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# Migration of Adult Chinook Salmon and Steelhead Past Dams and Through Reservoirs in the Lower Snake River and Into Tributaries - 1992

Annual Report for 1992

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# Evaluation of Passage of Adult Salmon and Steelhead at Lower Granite Dam and of Electronic and Underwater Video Technologies as Passage Evaluation Methods

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# MIGRATION OF ADULT CHINOOK SALMON AND STEELHEAD PAST DAMS AND THROUGH RESERVOIRS IN THE LOWER SNAKE RIVER AND INTO TRIBUTARIES - 1992

by

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## Abstract

A study of the upstream migration of adult spring and summer chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss* past the four lower Snake River dams, through the reservoirs, and into the tributaries of the Snake River drainage was initiated in 1991 and continued in 1992 and 1993. The objectives were to evaluate the effect of spill, powerhouse operation, and flows on the rates of passage of the fish at the dams, migration through the reservoirs, the fishway entrances used, fallback at the dams, and movements into the tributaries upstream from the reservoirs.

In 1992, 567 spring and summer chinook salmon and 694 steelhead were released with transmitters downstream and upstream from Ice Harbor Dam and monitored as they continued their migration to the spawning areas or hatcheries to assess migration rates and success. Spaghetti-loop and metal jaw tags were placed on 2,342 steelhead released upstream from Ice Harbor Dam during five periods of normal or zero flows at night from the three upper dams to assess the effect of reduced flow at night on migration. Oregon Department of Fish and Wildlife personnel conducted tests with electronic tunnels and underwater video at Lower Granite Dam to assess fishway entrance use and fallout by adult salmon and steelhead. The fishway fences installed near the north powerhouse entrances at the two upper dams in 1991 were maintained and evaluated further in 1992 to determine if fallout would be reduced from that observed in earlier years. Special scanning receivers and underwater antennas were installed at the entrances to the Lower Granite Dam fishway in summer 1992 to evaluate fishway use by steelhead and to test the capabilities of the new equipment.

Success of passage for the spring and summer chinook salmon can be measured in several ways. Based on counts of all adult chinook salmon passing through the fish ladders, 83% of the fish counted at Ice Harbor Dam were later counted at Lower Granite Dam in 1992. Salmon outfitted with transmitters survived the passage from the top of Ice Harbor Dam to the top of Lower Granite Dam at a rate similar (84.9%) to the untagged fish migrating up the river. Success of passage of steelhead with transmitters from the Ice Harbor Dam tailrace to the forebay at Lower Granite Dam and the upper end of the Lower Granite pool was an estimated 81.3% and

78.7%, respectively, in 1992 (87% and 75% in 1991) based on fish known to have passed through the ladder at Lower Granite Dam. Passage success was not affected by chinook salmon falling back over the dams in 1992. A total of 16 fallbacks among the salmon with transmitters were recorded at the four dams.

In 1992, about 59% of the fish with transmitters successfully migrated to natal streams or hatcheries versus 55% in 1991. There was evidence in 1992, as in 1991, that some fish apparently destined for hatcheries migrated to the vicinity of the hatcheries, but did not enter the hatcheries.

The distribution of spring versus summer chinook salmon in the Snake River basin varied by tributary. Timing of the migration in 1992 was earlier than normal because of low flows and turbidity during the spring runoff so the normal separation date of 11 June at Ice Harbor Dam between the spring and summer runs of chinook salmon was not useful in determining distribution of the two runs. Nonetheless, the relative composition of spring versus summer chinook salmon in many of the tributaries could be assessed by taking into account the composition in past years, the timing distribution in 1992, and using a separation date in the latter half of May.

The time required for chinook salmon to pass from the tailrace to the forebay of each Snake River dam ranged from a mean of 2.4 d at Ice Harbor Dam to 0.6 d/dam at Little Goose and Lower Monumental dams in 1992, versus a range of 7.9 to 1.8 d/dam in 1991. Median migration rates in 1992 ranged from 0.2 to 1.3 d. Migration rates through the reservoirs were more variable in 1992 than in 1991 (25 to 63 km/d, 1.0 to 3.1 mean days per reservoir). The rate of migration in the free flowing rivers based on mean days to pass was slower than in the reservoirs at 13 to 35 km/d, but similar to rates in 1991.

The relative distribution of spring and summer chinook salmon with transmitters into the tributaries of the Snake River basin in 1992 was 3.9% into the Tucannon River, 15.4% into the Clearwater River, 2.2% in the Snake River proper upstream from Lewiston, 10.3% into the Grande Ronde, 4.9% into the Imnaha, and 63.3% into the Salmon rivers.

In 1991, 2,710 steelhead were outfitted with transmitters or spaghetti-loop and jaw tags and released near Ice Harbor Dam. Eighty-two percent of those fish were recaptured in the trap at Lower Granite Dam. Forty-seven of the fish (1.5%) were last reported back down in the Columbia River or its tributaries, 8.5% were taken in the fishery or found dead in the Snake River downstream from Lewiston, 0.8% entered the Tucannon River, 4.4% were reported caught from the Snake River upstream from Lewiston or trapped at Hells Canyon Dam, 7.7% were taken in the fishery or returned to hatcheries in the Clearwater River basin, 2.5% ended up in the Grande Ronde basin, and 7.7% were last reported in the Salmon River basin. Based on transmitters, jaw tags, and spaghetti loop tags returned by anglers or agency personnel at hatcheries or trapping facilities, 147 of the tagged fish returned to hatcheries, and 736 (27.2%) were reported caught by anglers. The recapture rate by anglers is a minimum rate because we received mostly voluntary returns. The largest number of tagged steelhead recaptured at hatcheries occurred at Dworshak National Fish Hatchery with 63.

Three groups of steelhead were outfitted with radio transmitters and released in 1991, one in July at Hood Park downstream from Ice Harbor Dam, another in fall at Hood Park, and the third at Charbonneau Campground in fall upstream from Ice Harbor Dam. Steelhead released at Hood Park in July had the smallest proportion that migrated upstream past the four Snake River dams (18% recorded at Lower Granite trap during 1991 and the spring of 1992), followed by the group released at Hood Park in the fall (55%), and the group released at Charbonneau Campground in the fall (74%). Hatchery and naturally produced steelhead migrated successfully through the lower Snake River at similar rates, but more wild fish were recorded upstream from the reservoirs, perhaps because the fishery was selective for removal of hatchery fish.

Steelhead released at Hood Park in July of 1991 that passed over Lower Granite Dam in 1991, took an average of 40 d to return to the tailrace at Ice Harbor Dam, versus 9.4 d for the fish released in the fall (median days 48 and 2.8, respectively). Steelhead released at Charbonneau Campground in the fall of 1991 took 5.1 d on average (median 2.2 d) to reach the tailrace of Lower Monumental Dam. The mean time to pass each of the Snake River

dams ranged from 0.6 to 5.0 d/dam (medians 0.4 to 1.2 d) for fish released in the fall, with the longest mean time at Ice Harbor Dam, as was the case with chinook salmon. The rate of migration by steelhead through the reservoirs in the fall of 1991 was slower on average (4.9 to 25.1 km/d) than for chinook salmon. Mean migration rates of steelhead in the fall in the free-flowing rivers upstream from the Lower Granite pool were relatively slow (about 9.0 to 11.5 km/d) as expected because steelhead stop and spend the winter in the rivers.

Four groups of steelhead were outfitted with transmitters and released at Hood Park and Charbonneau campgrounds downstream and upstream from Ice Harbor Dam in 1992: 59 fish at Hood Park in July, 89 fish at Charbonneau in July, 258 fish at Hood Park in the fall, and 288 fish at Charbonneau in fall. Thirty-seven percent of the fish released in July at Hood Park were recaptured at the Lower Granite trap during the summer and fall of 1992 and the spring of 1993, compared to 36% of the fish released in July at Charbonneau, 51% of the fish released in fall at Hood Park, and 63% of the fish released in fall at Charbonneau Campground.

Steelhead released at Hood Park in July of 1992 with transmitters that passed over Lower Granite Dam in 1992, took an average of 40.5 d to return to the tailrace at Ice Harbor Dam, versus 11.2 d for the fish released in the fall (median days 46.1 and 5.1, respectively). The number of days steelhead took to return to Ice Harbor Dam after being released downstream was nearly identical for fish released in both 1991 and 1992. Steelhead released at Charbonneau Campground in July of 1992 that migrated past the dams in 1992, took 26.6 d on average to reach the tailrace of Lower Monumental Dam, compared to 5.6 d for fish released at the same location in the fall (median days 3.1 and 3.0 d, respectively). The mean time to pass each of the Snake River dams ranged from 1.0 to 6.8 d (medians 0.4 to 2.6 d) for fish released in the fall that passed over Lower Granite Dam in 1992. The rate of migration by steelhead through the reservoirs in the fall of 1992 averaged 13 to 27 km/d, about the same as for steelhead in 1991, and slower than for chinook salmon. Mean migration rates of steelhead in the fall of 1992 in the free-flowing rivers upstream from the Lower Granite pool were relatively slow (about 1 to 14 km/d), similar to that observed in 1991, because the steelhead

stop migrating and spend the winter in the rivers. Steelhead that were released in the summer and fall of 1992, but did not pass all of the dams in the lower Snake River until spring of 1993, often had longer passage times at one or more dams and slower migration rates through reservoirs than fish that passed all of the dams in the fall of 1992.

In the fall of 1992, steelhead with transmitters were monitored with new instantaneous-scan receivers as they approached, entered, and passed through the fishway at Lower Granite Dam to evaluate the new telemetry system and to evaluate passage into and through the fishway. Half of the steelhead monitored moved from the tailrace receiver up to the base of the dam and approached one of the entrances to the fishway within about 3 hours, entered the fishway within 5.5 hours, and passed over the dam within 27 hours. Most of the steelhead first approached the dam mainly along the southern half of the powerhouse, but with a significant number at the north powerhouse entrance facing into the spillway stilling basin. Steelhead approached the entrances many times (an average of 51 per fish) and those approaches were concentrated at the entrances at the south end of the powerhouse. The south shore-2, north powerhouse-3, and north shore entrances were the openings most used by steelhead to enter the fishway, and they had the highest net entry rates. The south shore-1 and north powerhouse-1 and -2 entrances had the poorest net entry rates. The fishway fence installed to prevent high exit rates from the north powerhouse entrances, seemed to have the opposite effect because many fish were found to move downstream in the collection channel, and then were guided into, instead of away from, those openings.

Steelhead use of the three north powerhouse entrances at Lower Granite Dam were also studied to determine which two of the entrances, when open together, were most effective. The north powerhouse-3 entrance had the most entries and least exits of the three, with the fishway fence in place.

The zero-flow test was continued in 1992, with 2,342 steelhead released with spaghetti-loop and jaw tags at Charbonneau Campground during the first 5 d of five two-week periods starting in early September and continuing into November. The pattern of movement by steelhead in the 5 groups through the lower Snake River, as measured by counts of tagged fish at the

dams, recaptures at the Lower Granite adult trap, and records of fish with transmitters, was similar in both 1991 and 1992. More of the fish in the second and third groups proceeded up the river than in the first and fourth groups. Water temperatures, high at first and then low by November, may have affected the timing and proportion of steelhead moving past the dams during the fall more than the flows at night. Migration rates of steelhead with transmitters through the three reservoirs affected by the zero or normal flows at night did not differ significantly in 1991 or 1992.

## Introduction

Adult spring and summer chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss* migrating to their natal streams in the Snake River basin must pass over eight dams and through as many reservoirs, four of which are in the lower Snake River. Losses of adults and delays in migration at each hydroelectric project must be kept to a minimum if we hope to succeed in maintaining the native runs of fish and achieve the Northwest Power Planning Council (NPPC) goal of doubling the abundance of fish in the future.

These studies address concerns of the Corps of Engineers (Corps) and section 603 of the NPPC's 1987 Columbia River Basin Fish and Wildlife Program, and the need to conduct studies to determine the effects of reduced and instantaneous flows on adult fish. Also included in the Program was the need to study fishway entrance use to determine the best flows and operating conditions.

The study was developed in consultation with Corps personnel, and in response to the high priority assigned to adult passage research in the Snake River by the Fish Research Needs and Priorities subcommittee of the Corps of Engineers' Fish Passage Development and Evaluation Program. The NPPC outlined adult passage problems in 1988 and urged that research be undertaken. In 1989, the Fish Passage Center recommended as top priority for the Corps' Walla Walla District, a study to verify which spill patterns at the Snake River dams will result in the least fallback.

Research has been conducted in the past by personnel of the Corps, Idaho Cooperative Fish and Wildlife Research Unit (ICFWRU), Oregon Department of Fish and Wildlife (ODFW), and National Marine Fisheries Service (NMFS) to evaluate passage rates, entrance and fallout in the passage facilities, fallback over the dams, spill and tailrace flow patterns, and migration rates with reduced nighttime flows at the Snake River dams. Facilities and operating procedures were modified as a result of earlier studies, and studies are needed to determine if the changes will result in the desired improvements. The studies by Turner et al. (1983, 1984) were conducted during only a part of the migration season and with an incomplete range of flow conditions, and they recommended further study. Some of the studies were conducted before the full complement of turbines had been installed in the Snake River dams.

Additional studies were needed to better define: (1) the effects of an extended period of zero flows at night on the passage of adult fish over the dams and through the

reservoirs, (2) the effect of spill configuration on the entry of fish into the fishway and the passage rate, (3) the rate of fallout from fishway entrances with a special fishway fence in the powerhouse collection channel, (4) the rate of fallback over the dams with various flow conditions, and (5) the distribution, migration rates, and survival of fish after they leave Lower Granite Dam.

Objectives for the studies conducted in 1992 were as follows:

1. Determine the effects of zero flow at night on migration rates, and on the proportion of adult steelhead passing each dam, entering the fisheries, and returning to hatcheries.

2. Determine the effects of quantity of spill and the patterns of spill on the rate of passage, and fishway entrance use by adult spring and summer chinook salmon at the four lower Snake River dams.

3. Evaluate the effectiveness of a fence installed in the fishway at Little Goose and Lower Granite dams for reducing the rate of fallout by adult salmon and steelhead at the powerhouse fishway entrances.

4. Assess the fishway entrance preferences of adult salmon and steelhead at Lower Granite and Little Goose dams under various conditions of flow, spill, and powerhouse operation.

5. Assess the rate of adult salmon and steelhead migration up the lower Snake River under various, normally occurring conditions of flow, spill, powerhouse operation, and season of the year.

6. Assess the rate and route of fallback adult salmon and steelhead over or through the lower Snake River dams under various conditions of spill, flow, powerhouse operation, and season of the year.

7. Determine the timing of migration, migration rates, distribution of fish, and survival rates of salmon and steelhead after they leave Lower Granite Dam.

The area of study extended from McNary to Priest Rapids dams on the Columbia River, the Snake River from the mouth of the river upstream to Hells Canyon Dam, all the

major Snake River tributaries, and at hatcheries where tagged fish were recovered. The work was divided into two major segments, tracking of fish outfitted with radio transmitters past the dams and into the tributaries by ICFWRU personnel, and monitoring of fishway entrance use at Lower Granite Dam with electronic tunnels and underwater video by ODFW personnel (Knapp and Knutsen 1993), and with special scanning receivers by ICFWRU personnel.

Studies to assess migration rates and passage success of adult spring and summer chinook salmon and steelhead at the lower Snake River dams and into the tributaries were conducted in 1992 using fish captured at Ice Harbor Dam (Figure 1) and outfitted with radio transmitters or spaghetti-loop tags. Radio transmitters were placed in 575 spring and summer chinook salmon (8 fish expelled the transmitters before release for a net release of 567) and 694 steelhead to monitor their passage at the dams and into the tributaries, to assess rates of migration, time to pass each dam, the number that fell back at each dam, distribution of fish into the tributaries, and the proportion that completed migrations to spawning grounds or hatcheries. Spaghetti-loop tags were used on 2,341 steelhead during the fall to evaluate the effects of zero flow at night on migration rates and passage success.

The influence of spill on migration rates, fishway entrance preferences, and fallback was not evaluated in 1992 because of the low volume of the spring runoff and lack of spill at Lower Granite and Little Goose dams. The effect of spills at Lower Monumental and Ice Harbor dams for juveniles during the spring will be analyzed using fish with transmitters.

The results of the radio telemetry studies in 1992 have been divided into three segments: migration rates, passage success, and distribution of chinook salmon, migration rates, passage success, and distribution of steelhead, and the effects of zero flow at night on steelhead migrations. The report on chinook salmon movements in 1992 is complete as most of the records of movements for chinook salmon were obtained from April through October 1992. The reports on steelhead movements are also mostly complete, and include fish tagged and released in the summer and fall of 1991 and 1992 with recovery data through the spring of 1994.

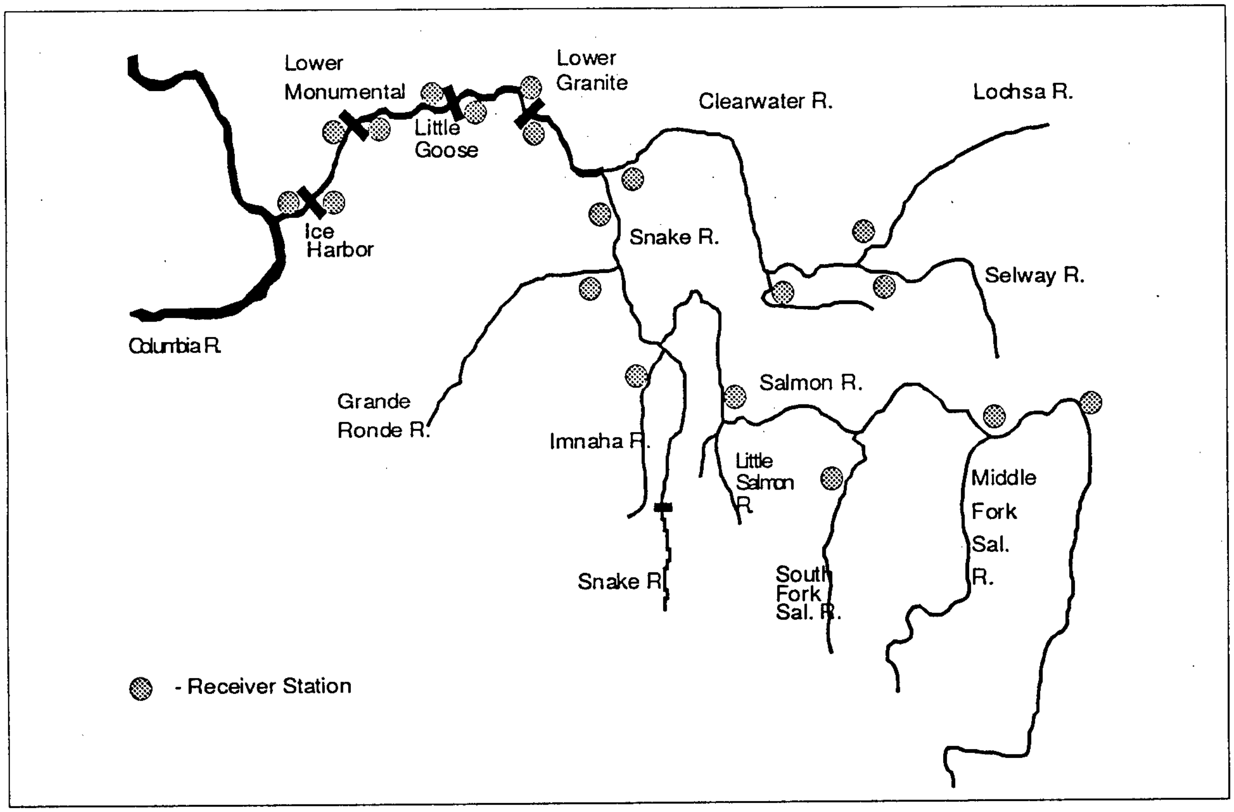



Figure 1. Map of the Snake River drainage and dams. Filled circles represent the location of receiver stations throughout the drainage during 1992.

## Chinook Salmon - 1992 Migration Rates, Passage Success, and Distribution

### *Methods*

The upstream migration of adult chinook salmon was monitored by releasing fish with radio transmitters at Hood Park (16.3 km downstream from Ice Harbor Dam near the mouth of the Snake River) and monitoring their migration at each of the dams and into the major tributaries using fixed-location receivers, mobile tracking receivers, and recapture of fish at traps, hatcheries, and recoveries from spawning grounds. The fixed-location receivers and associated antennas were installed at the dams and mouths of major tributaries in the spring of 1992 before the expected passage of fish with radio transmitters.

Fixed-location receivers were installed 0.5 to 2.7 km downstream from each of the four lower Snake River dams with two antennas at each site, and at the top of each fish ladder to determine when fish entered the tailrace area of each dam and left the top of the fishway. Receivers were also located on the powerhouse deck of each dam (with up to four underwater antennas each) at various fishway entrances and in the fishway collection

channel (Figure 2) to determine when fish had entered the fishway and their movements in the collection channel. All 6- and 9-element Yagi antennas used at forebay locations at each dam during the 1991 study, were removed for 1992. We found in 1991 that these sensitive antennas sometimes recorded fish off the back reception lobe of the antenna closest to the ladder while the fish were migrating up the ladders and had not exited into the forebay .

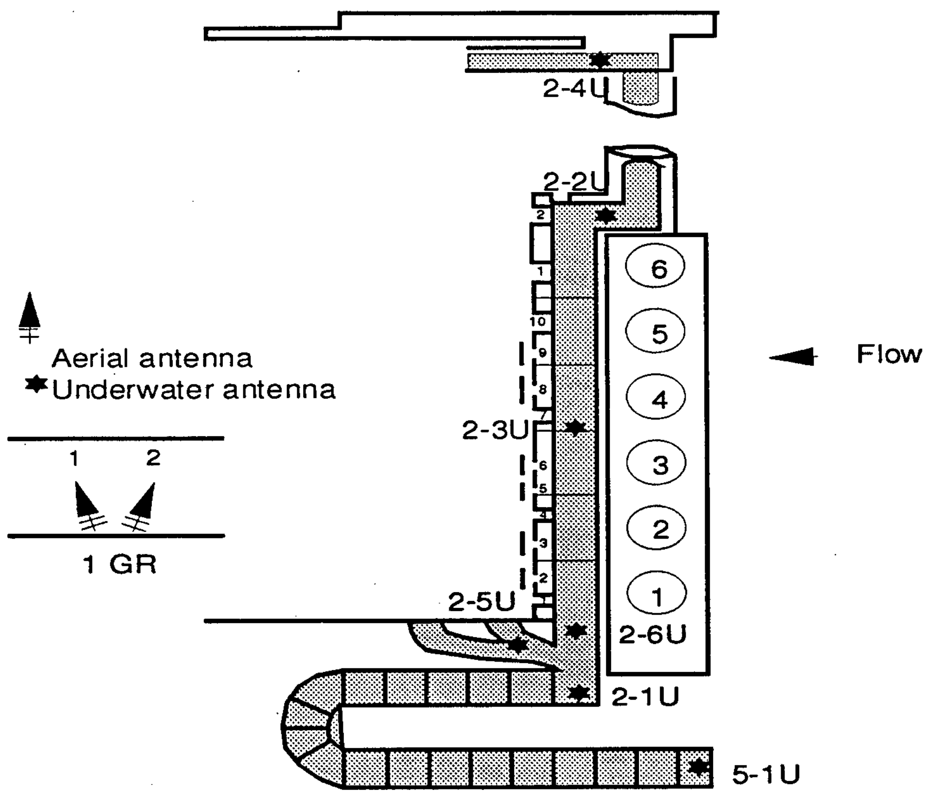



Figure 2. Drawing of a Snake River dam with locations of antennas in spring 1992. The first number of the receiver code is the receiver number, the second number is the antenna, and the letter U designates underwater versus aerial or surface antenna.

Three pickup trucks were outfitted with 4-element yagi antennas that could be rotated from within the cab to track fish with transmitters in areas not covered by fixed-location receivers. A boat was also set up for mobile tracking. Once the fish began to move upstream beyond the Lower Granite pool and into the tributaries, mobile tracking was initiated on a schedule that included checking streams with road access every two weeks or less. Mobile tracking in the tributaries continued into September until the salmon had spawned and died.

During the 1992 spring and summer chinook salmon runs, 560 adult fish (jacks were not tagged) were outfitted and released with radio transmitters at Hood Park and 7 summer chinook salmon were released with radio transmitters at Charbonneau Park, 1.7 km upstream of Ice Harbor Dam. Spring chinook salmon began passing over Ice Harbor Dam in early April. We began capturing fish and outfitting them with transmitters on 17 April and released the last fish on 15 July 1992 (Figure 3). Turbidity of the Snake River in the spring of 1992 was relatively low because of the small runoff. Secchi disk visibility at Ice Harbor Dam ranged from 4 to 7 feet during much of the runoff period. The upstream migration of adult chinook salmon was earlier than normal and the separation date for spring and summer chinook salmon may have been about 20 to 25 May (a nadir in the counts occurred then), rather than the 11 June date used in the annual fish passage reports (Corps of Engineers 1991). We used 1 June as the separation date in our initial analysis of the distribution of spring versus summer chinook salmon, but later decided that 25 May would be a more accurate separation date for 1992 because of the low, clear flows and rapid migration.

Of the 567 fish released with transmitters, 372 (66%) were released in April and May, and 195 (34%) were released in June and July (Figure 3). We ended up releasing 67 more fish with transmitters than the 500 planned by reusing transmitters from fish recaptured at hatcheries that were returned to us before the 15 July cessation of tagging. An unknown number (estimated to be 10%) of transmitters were faulty and failed prematurely (as discovered from fish recaptured at the Lower Granite trap) and were replaced by the manufacturer.

Based on counts compiled by the Fish Passage Center, using the traditional 11 June cutoff date, 25,460 adult spring chinook and 3,993 adult summer chinook salmon were counted at Ice Harbor Dam in 1992, with spring chinook salmon making up 86.6% of the total. Using the 25 May cutoff date, 23,709 of the fish would be classed as spring chinook (80.5% of total adults) and 5,685 as summer chinook salmon. Fifty-six percent of the chinook salmon we outfitted with transmitters in 1992 were tagged by 25 May.

The radio transmitters and receivers used in 1992 were manufactured by Lotek Engineering Inc., of Newmarket, Ontario, Canada and Yagi antennas by Cushcraft. The transmitters (80 mm X 16 mm) emitted a digitally coded signal every 5 seconds that could be interpreted by the receiver as a unique numeric code and recorded in a data bank along with the channel (frequency of the transmitter), relative power of the signal, antenna

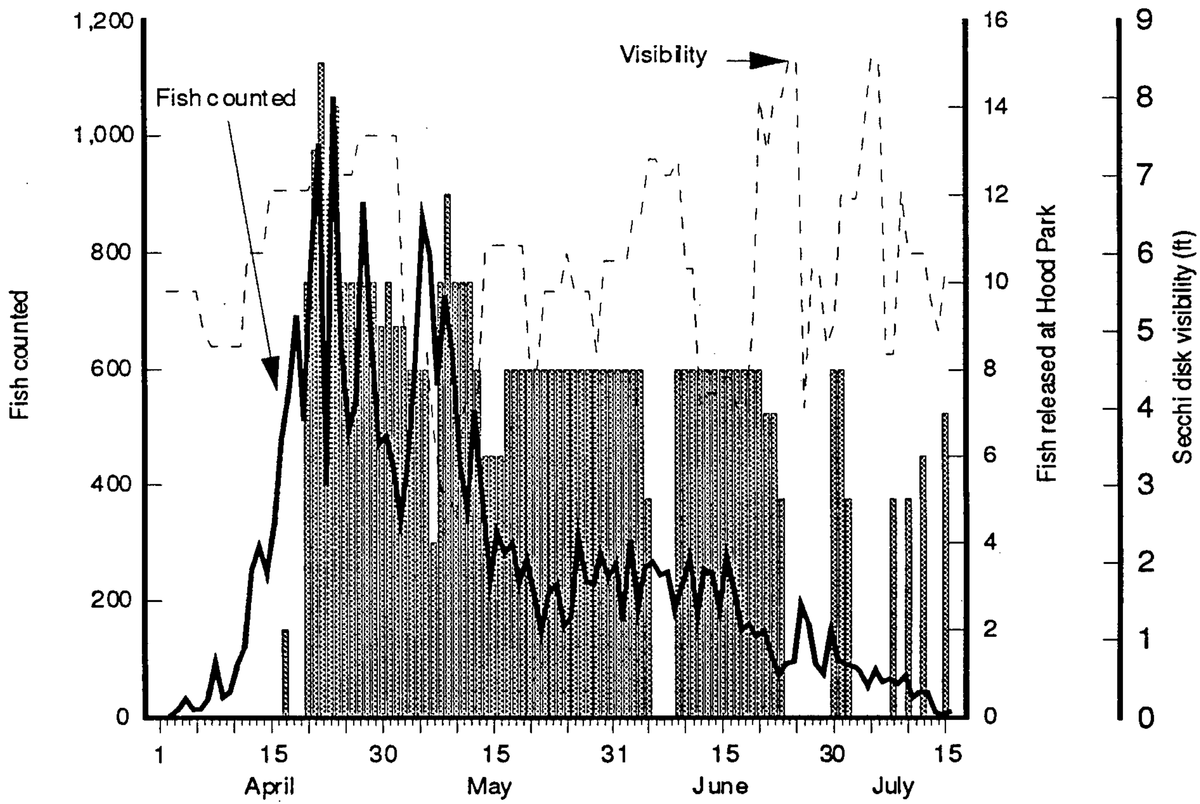



Figure 3. Chinook salmon counted at Ice Harbor Dam, salmon tagged and released (bars), and secchi disk visibility at the dam in 1992.

receiving the signal, date, and time. There were eight data banks in the receiver that could store a total of about 64,000 records. The receiver data banks were downloaded as files in a portable computer every 1 to 4 weeks depending on the location and fish activity at the site. Receiver reliability was high in general, with few gaps in the data resulting from loss of electric or battery power, or from receiver malfunction (Figure 4).

Chinook salmon outfitted with transmitters (inserted into the stomach through the mouth) in 1992 ranged in size from 61.5 cm to 98.5 cm fork length, a size range that included fish that had spent two or three years in the ocean. In 1991, larger transmitters than those used in 1992, were used and the fish outfitted with transmitters had to be 70 cm or longer fork length. All of the hatcheries with predominantly spring chinook salmon (Rapid River, Lookingglass, Kooskia, and Dworshak) had more two-ocean than three-ocean fish in 1992 (Figure 5). In the hatcheries with more summer chinook salmon (South Fork/McCall, Pahsimeroi, and Sawtooth) three-ocean fish made up a large part of the fish returning in 1992.

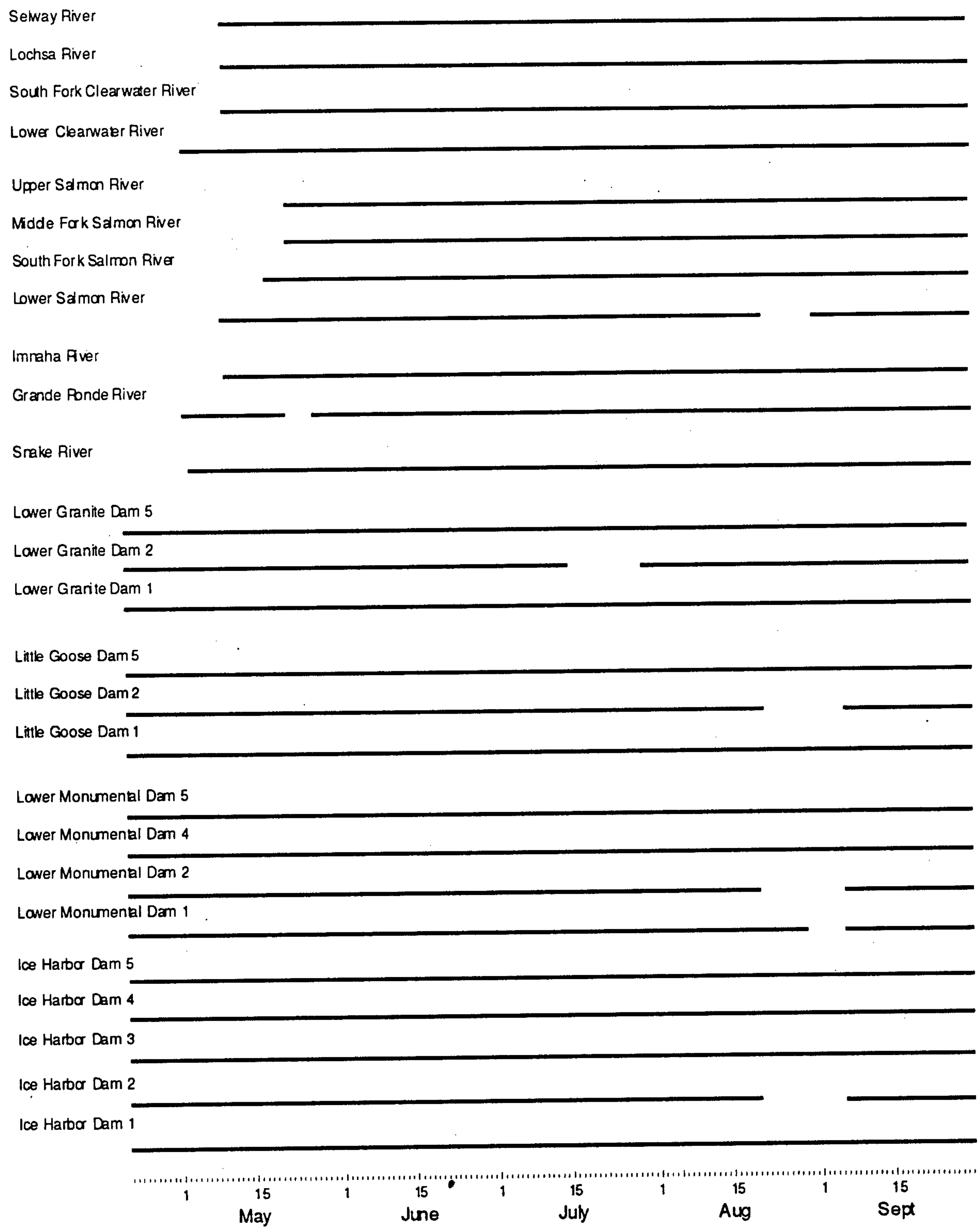



Figure 4. Diagram to illustrate periods of operation of fixed-location receivers at dams and tributaries in the Snake River basin in 1992. Breaks in the lines represent periods of non operation.

In addition to the radio transmitter, all fish released were tagged with a numbered aluminum band on the lower jaw, and a coded-wire tag inserted in the muscle near the dorsal fin. The jaw tag was used as a backup means of identifying fish released with transmitters, and the coded-wire tag was used to trip the detector at the adult trap in the ladder at Lower Granite Dam.

The usual trapping and tagging operation started at about 9:00 am each morning by lowering screens into the V-weir opening in the top pool of the south ladder at Ice Harbor Dam to guide fish into the trap box where they could be observed and selected or allowed to continue their migrations. Fish that were suitable for tagging with a transmitter were diverted from the trap box into an adjacent holding pen until the number needed had been collected. The holding pen was then lifted by crane to the top roadway across the dam and the fish deposited in an insulated tank on a truck. The lower 45 cm of the holding pen was constructed of sheet metal to retain water when lifted from the ladder so the fish were always in water. A canvas sleeve attached to a hole in the bottom of the holding pen was used to transfer the fish from pen to tank. Water in the tank was obtained from the forebay at the dam and anaesthetic (MS222) was added (one-half the normal dose) before the fish were put in the tank.

The fish were then taken downstream to Hood Park where they were taken from the tank one at a time via a slick-sided bag and placed into a large plastic tub containing a full dose of anaesthetic. Each fish was examined for marks, measured, jaw and coded-wire tagged, outfitted with a transmitter, and then placed in a pen in the river for about 1 hour to recover. The holding period in the recovery pen was primarily to check for transmitter retention immediately after tagging. After recovery and the fish were released, the pen was checked for transmitters that had been regurgitated by fish while in the recovery pen. Transmitters found in the pen were reused in another fish and the records changed to indicate which fish had regurgitated a transmitter.

The migrations of fish with transmitters and jaw tags were recorded in numerous ways starting with release at Hood Park, recording of passage on the fixed-location receivers at the dams and at mouths of the major tributaries, sitings by the mobile trackers, recaptures at the Lower Granite adult trap and at weirs and hatcheries throughout the basin, and recoveries of spawned fish in the tributary spawning areas. Information on some fish was provided by people operating traps at Priest Rapids Dam on the Columbia River, at Three-Mile Dam on the Umatilla River, and by people finding fish or transmitters along the river

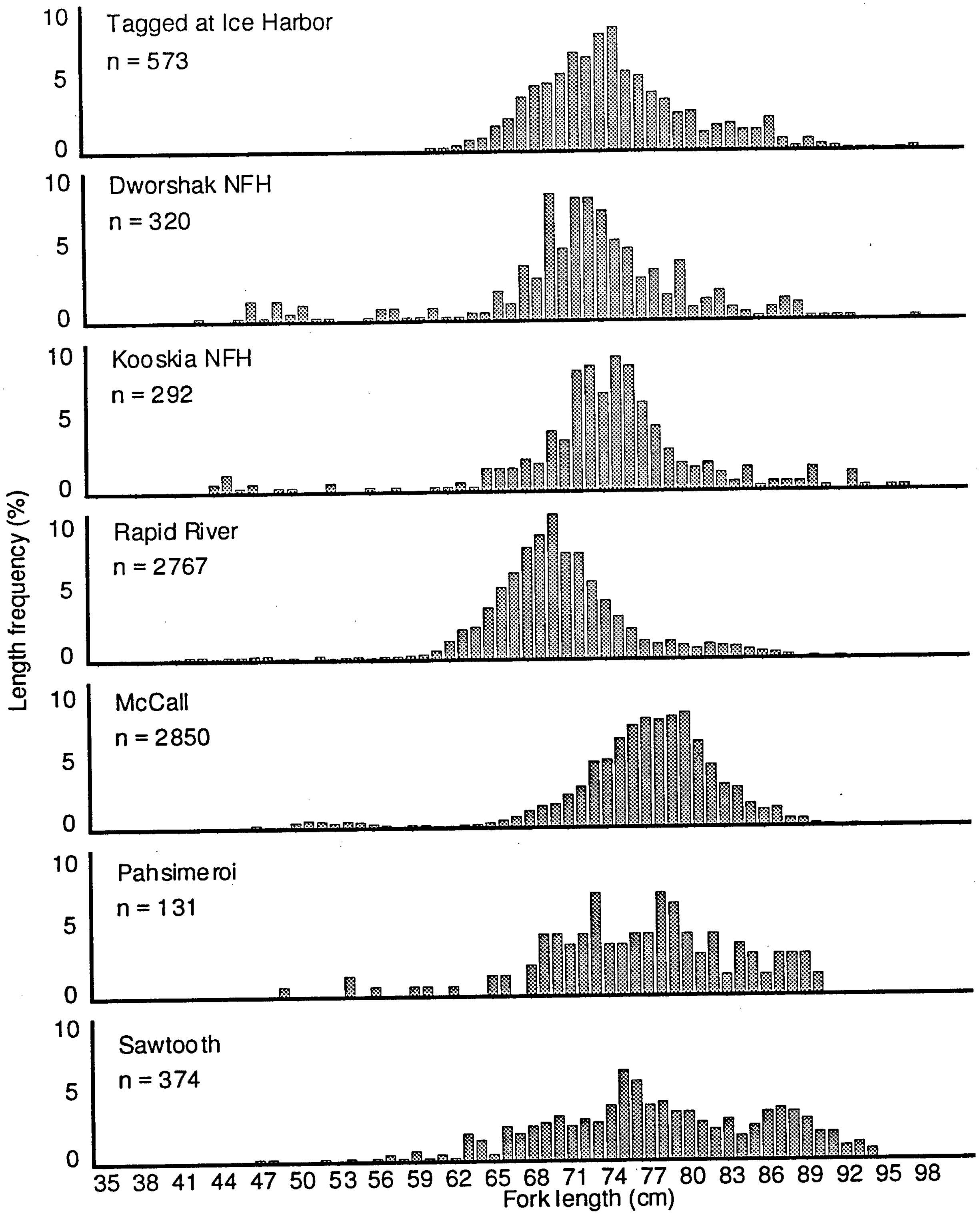



Figure 5. Length frequency distribution of spring and summer chinook salmon outfitted with transmitters at Ice Harbor dam in 1992, and salmon returning to the various hatcheries in the Snake River basin.

banks. Each record of a siting or recapture was added to a database and used to decipher the movements of each individual fish (Figure 6).

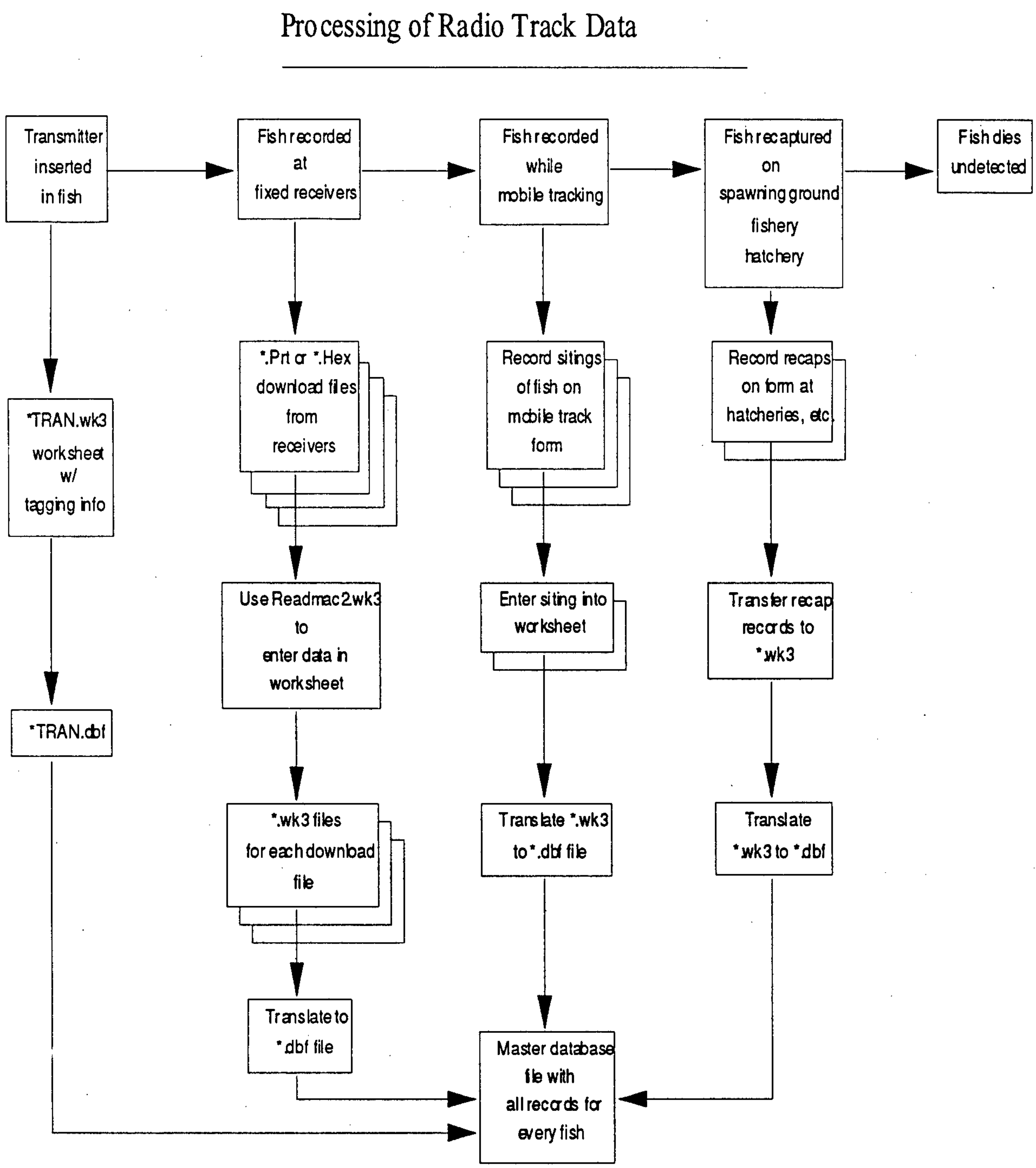



Figure 6. Diagram illustrating the steps taken to process the different sources of radio tracking data (e.g., fixed-site receivers, mobile tracking, recaptures, etc.) for inclusion in a master database file for each species and dam.

### *Results*

***Passage success.***- Of the 560 spring and summer chinook salmon released at Hood Park with transmitters in 1992, 519 were recorded as entering the tailrace at Ice Harbor Dam, 497 at Lower Monumental Dam, 491 at Little Goose Dam, 463 at the Lower Granite Dam tailrace (Figure 7). In addition, 422 of the fish were recorded passing over Lower Granite Dam (81.3% of the fish moving up to Ice Harbor Dam after release), and 396 fish (76.3%) were last recorded upstream from Lower Granite Reservoir. After removing the 16 fish that entered the Tucannon River, the survival of chinook salmon with transmitters from the Ice Harbor Dam tailrace to upstream of Lower Granite Reservoir was at least 78.7% (396 / (519 - 16)).

Of the 7 summer chinook salmon released at Charbonneau Campground, 6 were subsequently relocated. Four were recorded at Lower Monumental Dam and three of those passed the dam. Of those three, one was never recorded again, one was recorded at the tailrace location at Little Goose Dam and never heard from again, and the third fish crossed Little Goose Dam, arrived at the tailrace location of Lower Granite Dam and was

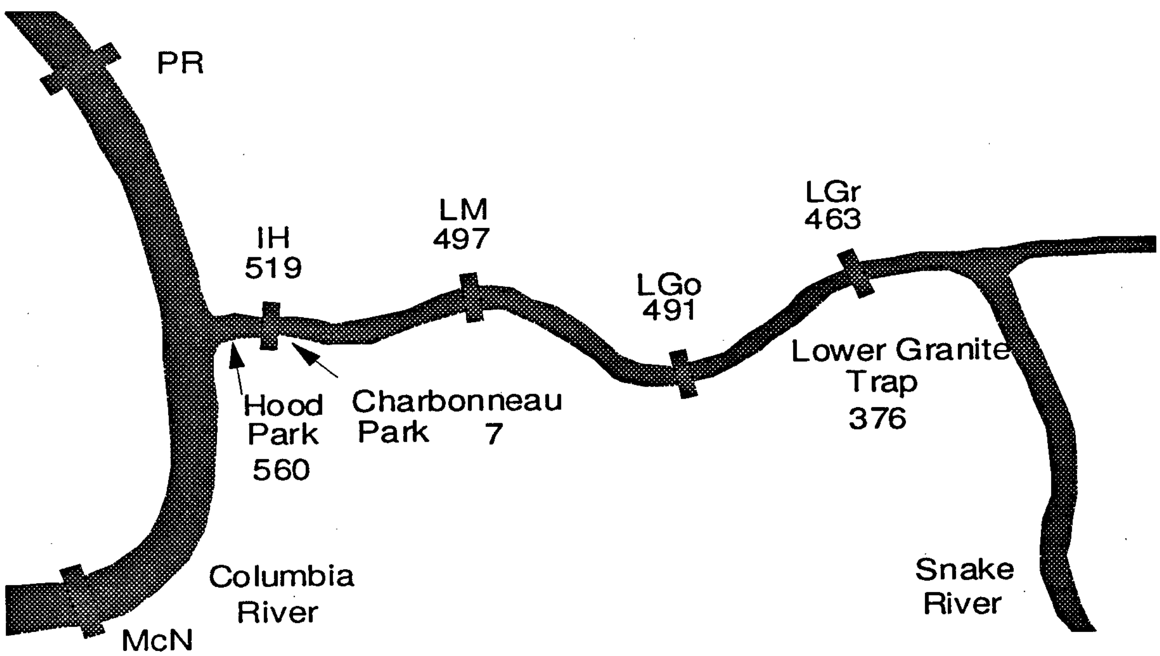



Figure 7. Map of the lower Snake River with the number of spring and summer chinook salmon released with transmitters at Hood Park and Charbonneau campgrounds and those that were subsequently recorded on receivers in the tailraces downstream from each of the four Snake River dams or captured at the Lower Granite adult trap in 1992.

never heard from again. Two of the three remaining fish released at Charbonneau Park fell back over Ice Harbor Dam and exited the Snake River to the Columbia River, where they were logged at least once by mobile trackers.

Few chinook salmon with transmitters fellback over the dams in 1992, a year with low flows and lack of spill. Seventeen fallbacks occurred; 8 at Lower Granite (1.8% of the 422 salmon that crossed the dam), 6 at Little Goose, 1 at Lower Monumental, and 2 at Ice Harbor dams. These numbers include two fish that fell back from Lower Granite and Little Goose dams and subsequently entered the Tucannon River. Of the eight Lower Granite Dam fallbacks, only one successfully reascended the dam and was eventually recorded at an upstream site (Lochsa River). All others went downstream at least as far as the tailrace of Little Goose Dam. Three of the six fallbacks at Little Goose Dam reascended, then crossed over Lower Granite Dam. One of these fish was never recorded or recaptured after crossing Lower Granite, one fish ended up at the Middle Fork Salmon River, and the third fish crossed Lower Granite Dam, then fell back down to the tailrace at Lower Monumental Dam. Of the three fallbacks that did not reascend Little Goose Dam, two ended up below Ice Harbor Dam and the third exited the Snake River to the Columbia River and was lost. Corps of Engineers personnel counted the number of salmon without transmitters that fell back through the bypass system at Lower Granite Dam in 1992 and reported 87 adults and 3 jacks during the April through July period (about 0.4% of the 21,924 salmon counted).

Of the 519 fish detected in the Ice Harbor Dam tailrace, 497 crossed over the dam. Including the 7 fish released at Charbonneau Campground, 504 fish were available to migrate upstream from Ice Harbor Dam. Of those, 497 salmon were detected in the tailrace of Lower Monumental Dam, and 497 passed the dam. Of the 491 fish known to have travelled from the forebay of Lower Monumental Dam to the tailrace below Little Goose Dam, 474 crossed Little Goose Dam. Of the 463 fish migrating from the forebay of Little Goose Dam to the tailrace of Lower Granite Dam, we recorded 422 fish as having passed over Lower Granite Dam (fish recorded at the Lower Granite trap, at the top of the ladder, or at receivers upstream from the reservoir).

The Lower Granite trap was closed down 27 June to 6 July, and 27 July to 9 September in 1992 because of high water temperatures, so portions of the chinook salmon run were not recorded at the trap. The numbers of chinook salmon recorded at the trap or on receivers provide minimum survival rates because the trap and the receivers located downstream from each dam or at the tops of the ladders were not 100% efficient. Long

receiver scan times (monitoring several frequencies) at the top of fish ladders may have caused us to miss some fish exiting fish ladders, despite the use of looping-coaxial-cable antennas. At the tailrace receivers downstream from the dams, a fish swimming past in the deepest part of the channel might not get recorded (range limited to water depths less than 12 m), and there were brief periods when each receiver was out of operation for service or because of a malfunction. Receiver scan times were probably too long to record passage of every radio-tagged fish approaching Lower Granite Dam in 1992, because the tailrace receiver was also used to scan for transmitters placed in squawfish *Ptychocheilus oregonensis*. For example, of the 463 fish known to have arrived at Lower Granite Dam (recorded at a receiver in the fishway), 50 (10.8%) were not logged on the tailrace receiver. The tailrace area was a noisy reception environment because of boat activity and this contributed to the mediocre performance of this receiver. At other dams with fewer frequencies to scan, receiver performance was better. Of 497 fish known to have arrived at Lower Monumental Dam, 36 (7.2%) were not logged on the tailrace receiver; at Little Goose Dam, 36 of 491 fish (7.3%) known to have passed through the tailrace were not detected.

Extending the reception area in the top 3-4 pools of the fish ladders by using looping-coaxial-cable underwater antennas in 1992 improved our ability to detect fish exiting the ladders at the tops of the dams. In addition, primary ladders at Lower Monumental (north) and at Ice Harbor (south) and fish ladders at Little Goose and Lower Granite dams were each monitored by a single dedicated receiver and antenna to minimize scan times and collisions, and maximize our chances of detecting all fish exiting the tops of fish ladders. As a result of these modifications, of 496 fish known to have crossed Ice Harbor Dam (recorded at a site upstream from the dam), 470 (94.8%) were recorded on the receivers at the tops of the ladders. At Lower Monumental Dam, 95% (472/497) of the migrants were recorded crossing the dam, and percentages of fish recorded when crossing Little Goose and Lower Granite dams were 97.8% (461/474) and 98.8% (417/422), respectively.

Of the 422 fish outfitted with transmitters that we know passed over Lower Granite Dam; 8 fell back over the dam, with 2 entering the Tucannon River, 3 recrossed the dam and were not recorded again, and 3 disappeared in the Little Goose pool. Ten other fish crossed Lower Granite Dam and were never detected again after exiting the top of the fish ladder. Three more fish were described as being in poor shape when released by Lower Granite trap personnel, and the fish were not recorded upstream or downstream from the

dam. Three fish made two complete trips through all but the Lower Granite pool, and although classified as fallbacks, they eventually successfully crossed Lower Granite Dam.

Of the 422 fish passing over Lower Granite Dam, 417 were available to enter either the Snake or Clearwater rivers upstream from Lower Granite Reservoir (422 minus the 5 fish that fell back over the dam and did not reascend). Sixty-three fish (14.9%) were found to have entered the Clearwater River, and 330 (78.2%) the Snake River upstream from Lower Granite Reservoir (Table 1). The remaining 29 fish (7.0%) were not recorded upstream from Lower Granite Reservoir. As mentioned before, we know that 5 fish fell back over Lower Granite Dam and did not reascend. Of the remaining 24 fish (5.8%), some may have died in the Lower Granite pool or in upstream rivers, and some may have regurgitated transmitters after passing Lower Granite Dam, but survived to spawn undetected by our monitoring. The 396 fish that entered either the Clearwater or Snake rivers upstream from the reservoir amounted to 78.7% of the 519 fish that had moved upstream to the tailrace of Ice Harbor Dam after release, adjusted for the 16 fish that entered the Tucannon River. Of the 497 chinook salmon with transmitters that crossed over Ice Harbor Dam, 422 crossed over Lower Granite Dam for a minimum survival rate of 84.9%, a rate similar to that calculated from counts of adult spring and summer chinook salmon at Ice Harbor and Lower Granite dams in 1992 (24,405/29,394 = 0.83).

Fish distribution throughout the Snake River basin was analyzed on the basis of last sitings of fish while mobile tracking, recordings at receivers, recaptures at weirs or hatcheries, and recoveries on spawning grounds or along the rivers. Of the 567 fish released at Hood and Charbonneau campgrounds in 1992, 19 were never recorded after release, 23 others migrated downstream out of the Snake River into the Columbia River, 10 were located in the Snake River downstream from Ice Harbor Dam one or more times, but that was the last siting, and 18 fish were recorded at Ice Harbor Dam at least once, but they never crossed over the dam (Table 1). Based on the analysis of migration records, at least 4.0% of the salmon with transmitters did not stay in the Snake River, and another 8.3% either died in the Snake River downstream from Ice Harbor Dam or moved downstream into the Columbia River where they died or migrated into other streams undetected. The combined numbers of fish leaving the Snake River or dying before proceeding up the Snake River past Ice Harbor Dam (70 fish, 12.3% of those released) may not be unusual for a confluence of two large rivers, but we do not know if the rate is higher than usual because of our trapping and tagging of the fish at Ice Harbor Dam.

The Lower Granite Dam tailrace and reservoir were the last places that 67 of the fish were located (Table 1). A few of those fish may have moved up beyond the Lower Granite pool, but were undetected by fixed-location receivers or mobile trackers. Fish that regurgitated transmitters in the Lower Granite pool, but were recaptured at hatcheries or fish weirs were identified if they still had the jaw tag and have been included in Table 1. Those that migrated into tributaries where they were unlikely to be found by spawning ground survey crews would not have been detected. The 132 fish that were last recorded between Hood Park and the upper end of Lower Granite Reservoir amounted to 23.3% of the 567 fish released, and 25.1% (132/525) of the fish located after release and likely to go up the Snake River. With the 16 fish that entered the Tucannon River removed from the last sitings, the percentage becomes 22.1 (116/525) and could be considered a maximum estimate of fish that did not survive the migration between Hood Park and the upper end of Lower Granite Reservoir. This estimate is a maximum estimate because a few fish may not have been detected in rivers and streams upstream from the Lower Granite pool. In addition, the trapping and tagging of the fish may have increased the loss rate, however, the similarity of passage rates between Ice Harbor to Lower Granite dams based on tagged fish in this study (84.9%), versus regular counts at the dams (83%) is evidence that tagging effects may have been small. The fraction of the "loss" that can be ascribed to the dams versus natural causes is unknown.

Upstream from the reservoirs, salmon enter the Clearwater River or continue up the Snake River. In 1992, the Clearwater River and its tributaries were the last locations for 63 (11.1%) of the fish released at Hood Park (Table 1). One fish entered Kooskia National Fish Hatchery, 2 fish entered Dworshak National Fish Hatchery, and 31 entered the other major tributaries (Lolo Creek, South Fork, Selway, and Lochsa rivers). The 29 remaining fish were located throughout the Clearwater River from the mouth up to the Selway River. Five of the 29 fish were recorded at the fixed-location receiver near the mouth of the river, and two of the five moved back downstream and entered the Snake River. Six fish were located immediately downstream from Dworshak National Fish Hatchery and the remainder of the fish were spread along the length of the river and not concentrated at any given location. Similar to 1991, a few fish were concentrated near Dworshak National Fish Hatchery (mouth of the North Fork, Figure 8) and the remainder were spread out in the Clearwater River from the mouth to just above the mouth of Clear Creek, the water supply for Kooskia National Fish Hatchery.

Table 1. Recapture location or last siting of spring and summer chinook salmon outfitted with transmitters and released downstream from Ice Harbor Dam at Hood Park and upstream at Charbonneau Park in 1992. Last sitings were at fixed location receivers or by mobile trackers. Recaptures were at hatcheries, fish weirs, during spawning ground surveys, and by people who found fish along the rivers.

| Location-description | Number of fish | Percent of fish |
|---|---|---|
| Hood Park release site | 18 | 3.17 |
| Charbonneau Park release site | 1 | 0.18 |
| Subtotal | 19 | 3.35 |
| Columbia River | | |
| Downstream from the Snake River | 13 | 2.29 |
| Umatilla River | 6 | 1.06 |
| Upstream from the Snake River | 4 | 0.70 |
| Subtotal | 23 | 4.05 |
| In the lower Snake River | | |
| Downstream from Ice Harbor Dam | 10 | 1.76 |
| Ice Harbor Dam tailrace | 18 | 3.18 |
| Lower Monumental Dam and pool | 5 | 0.88 |
| Tucannon River | 16 | 2.82 |
| Little Goose Dam and pool | 16 | 2.82 |
| Lower Granite Dam and pool | 67 | 11.82 |
| Subtotal | 132 | 23.81 |
| Clearwater River drainage | | |
| Clearwater River | | |
| Receiver site | 5 | 0.88 |
| Dworshak National Fish Hatchery | 2 | 0.35 |
| Mouth to North Fork | 15 | 2.65 |
| North Fork to Selway River | 9 | 1.59 |
| Lolo Creek | 3 | 0.53 |
| South Fork Clearwater | 1 | 0.18 |
| Crooked River | 2 | 0.35 |
| Red River | 1 | 0.18 |
| Kooskia National Fish Hatchery | 1 | 0.18 |
| Selway River | 6 | 1.06 |
| Lochsa River | 18 | 3.17 |
| Subtotal | 63 | 11.11 |
| Snake River-Lewiston to Hells Canyon Dam | 9 | 1.59 |

Table 1. continued.

| Location-description | | Number of fish | Percent of fish |
|---|---|---|---|
| Grande Ronde River drainage | | | |
| Receiver site | | 4 | 0.70 |
| Grande Ronde River | | 4 | 0.70 |
| Lookingglass Creek | | 2 | 0.35 |
| Lookingglass Fish Hatchery | | 7 | 1.23 |
| Catherine Creek | | 2 | 0.35 |
| Wenaha River | | 6 | 1.06 |
| Wallowa River | | 4 | 0.70 |
| Bear Creek | | 1 | 0.18 |
| Minam River | | 9 | 1.59 |
| Lostine River | | 3 | 0.53 |
| | Subtotal | 42 | 7.41 |
| Imnaha River drainage | | | |
| Imnaha River | | 19 | 3.35 |
| Imnaha River weir | | 1 | 0.18 |
| | Subtotal | 20 | 3.53 |
| Salmon River drainage | | | |
| Lower Salmon River-mouth to Riggins | | 31 | 5.47 |
| Slate Creek | | 1 | 0.18 |
| Little Salmon River | | 15 | 2.65 |
| Rapid River | | 20 | 3.53 |
| Rapid River Fish Hatchery | | 27 | 4.76 |
| Hazard Creek | | 2 | 0.35 |
| Middle Salmon River-Riggins to North Fork | | 4 | 0.71 |
| South Fork Salmon River | | | |
| Receiver site | | 3 | 0.53 |
| South Fork | | 49 | 8.64 |
| Secesh River | | 3 | 0.53 |
| Lake Creek | | 3 | 0.53 |
| East Fork of South Fork | | 6 | 1.06 |
| Johnson Creek | | 8 | 1.41 |
| South Fork weir | | 40 | 6.05 |

Table 1. continued.

| Location-description | Number of fish | Percent of fish |
|---|---|---|
| Middle Fork Salmon River | | |
| Middle Fork Receiver site | 12 | 2.12 |
| Big Creek | 4 | 0.71 |
| Loon Creek | 1 | 0.18 |
| Sulphur Creek | 1 | 0.18 |
| Bear Valley Creek | 3 | 0.53 |
| Elk Creek | 2 | 0.35 |
| Marsh Creek | 1 | 0.18 |
| Monumental Creek | 1 | 0.18 |
| Rush Creek | 1 | 0.18 |
| Upper Salmon River - upstream from North Fork | | |
| Salmon River | 6 | 1.06 |
| Lemhi River | 3 | 0.53 |
| East Fork Salmon River | 3 | 0.53 |
| Herd Creek | 2 | 0.35 |
| Sawtooth Fish Hatchery weir | 7 | 1.23 |
| Subtotal | 259 | 45.68 |
| Grand total | 567 | 100.00 |

The Grande Ronde basin was the last location of 42 (7.4%) of the fish released with transmitters (Table 1). Four fish were recorded entering the river on the receiver 1.6 km upstream from the mouth and not located again. Four fish were last seen in the Grande Ronde River, seven entered Lookingglass Fish Hatchery, two remained in Lookingglass Creek and the remainder were located in other tributaries, mainly the Minam and the Wenaha rivers.

The Imnaha River was the last location for 20 (3.53%) chinook salmon released with transmitters in 1992 (Table 1). All 20 fish recorded at the Imnaha River receiver located near Fence Creek, 23 km upstream from the mouth, were later located upstream. Nineteen fish were last recorded in the Imnaha River upstream from the receiver site, and one fish entered the Imnaha River weir. There was a concentration of radio-tagged fish downstream from the weir (1 - 8 km) in what appeared to be suitable spawning habitat, and natural spawning probably occurred in this stretch of the Imnaha River in 1992.

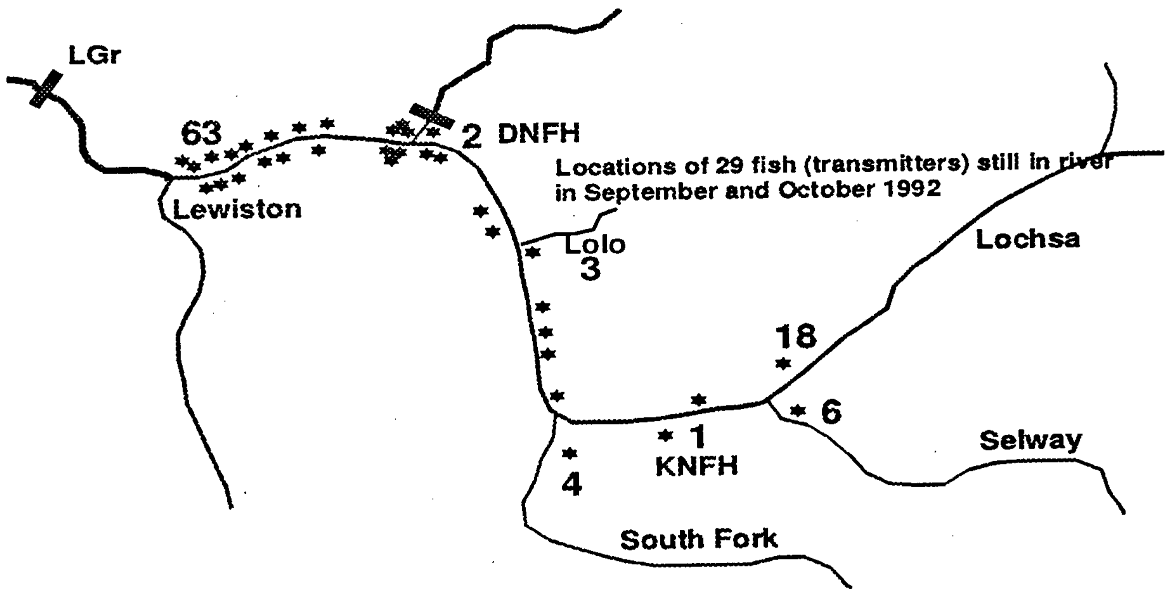



Figure 8. Map of the Clearwater River drainage with the number of chinook salmon with transmitters entering each of the major tributaries (numerals) and the distribution of salmon (transmitters) along the mainstem Clearwater River in September and October 1992 (stars).

The Salmon River was the apparent destination of the largest proportion of the chinook salmon released with transmitters; 259 of the fish (45.7%) were last located in that drainage (Table 1). Thirty-one fish (5.5%) were last recorded in the lower Salmon River from the mouth upstream 138.7 km to Riggins, and most of these fish probably died before spawning because the lower Salmon River is not known as a spring or summer chinook spawning area. One fish was located in Slate Creek by mobile tracking. The Little Salmon River tributary was the last location for 15 fish (2.7%). Forty-seven fish (8.3%) entered Rapid River; 20 were last located in the river (0-1.6 km) below the trap, and 27 were caught at the trap and taken to Rapid River Fish Hatchery. Although most of the 62 fish (10.9%) in the Little Salmon and Rapid Rivers were probably destined for the hatchery, many spawned in the streams downstream from the trap. Only four fish were last recorded in the Salmon River between Riggins and North Fork, and most of those may have been fish that died before spawning.

The South Fork, the next major drainage up the Salmon River from Riggins, was the last location for 112 spring and summer chinook salmon (19.8%) (Table 1). Three were last recorded at the receiver site, 1 km downstream from the mouth of the Secesh River,

49 were found in the main stem South Fork between the receiver site and the fish weir near Knox Bridge, eight were found in Johnson Creek and three each in the Secesh River and Lake Creek. The East Fork of the South Fork was the last known location of six fish, and 40 fish were captured at the South Fork Salmon weir. There was no way to estimate mortality within the South Fork.

In the Middle Fork drainage, 26 fish were found in several tributaries and 12 fish were last recorded at the receiver at the mouth of the Middle Fork (Table 1). Because much of the drainage is unroaded, our coverage was less complete than in other basins. Some of the 12 fish may have died before spawning, but we do not know the number.

Of the 21 fish (3.7%) last recorded in the upper Salmon River basin upstream from North Fork, 6 were last recorded in the Salmon River, 3 were found in the Lemhi River, 3 were located in the East Fork Salmon River and 2 in Herd Creek, and 7 were trapped at the Sawtooth Fish Hatchery weir (Table 1).

In summary, the distribution of fish released with transmitters by section or drainage in the Snake River basin in 1992 was as follows: 4% left the Snake River after release and we are assuming these fish really were not destined for Snake River tributaries and 22% did not get upstream beyond the Lower Granite pool. Nineteen additional fish were never located after tagging, and either died or exited the Snake River to the Columbia River. Three percent of the transmitters were recorded in the Tucannon River, the Clearwater River drainage had 11.1% of the last-record fish, 1.6% were last recorded in the Snake River upstream from Lewiston, 7.4% were recorded in the Grande Ronde basin, 3.5% entered the Imnaha River, and 45.7% ended up in the Salmon River (Table 1). If we assume fish lost in the lower Snake River (116) were destined for the tributaries in the same proportions as the survivors, then the distribution by Snake River tributary becomes 3.9% in the Tucannon River, 15.4% destined for the Clearwater River, 2.2% destined for the Snake River upstream from Lewiston, 10.3% destined for the Grande Ronde River, 4.9% destined for the Imnaha River, and 63.3% destined for the Salmon River.

An estimate of the number of fish with radio transmitters that died before spawning can be made on the basis of the last place the fish were located. Such estimates contain both negative and positive biases, because fish last located in a section of river where spawning has not been seen (usually main stems of the major tributaries) were counted as fish that died prematurely, and fish located in a spawning stream would be counted as a fish that spawned. In the first case, the fish may have spawned where located or in a

tributary upstream, but was not detected. In the second case, not all fish that make it to a stream used for spawning survive and spawn.

Of the 519 chinook salmon with transmitters that we believe tried to migrate up the Snake River after being released at Hood Park, 116 (22%) were not located upstream from the four lower Snake River dams and reservoirs or in the Tucannon River (Table 1), and can probably be classed as fish that died prematurely, although a few may have passed upstream undetected. In the Clearwater River drainage, 29 of the 63 fish found in that basin were last seen in the main stem Clearwater River between the mouth and the Selway River. Spring and summer chinook salmon have not been seen spawning routinely in the river so many of those fish may have died before spawning or entering the two hatcheries in that section of stream. If they were losses, they would increase the loss rate to 27.9% (145/519). The nine fish last recorded in the Snake River between Lewiston and Hells Canyon Dam, another stretch with no history of spawning for these fish, would increase the loss to 29.7%. We know of no fish that died before spawning in the Imnaha River and could not class any of the fish entering the Grande Ronde River as losses, although some probably occurred. In the Salmon River, 32 fish were last located downstream from Riggins, and 8 were last found between Riggins and North Fork, both stretches of river with no history of spawning. Twenty-four fish were last located in the Salmon River upstream from North Fork and could have spawned, no fish were found dead and unspawned in that section of river in 1992. Some of the fish that entered the South and Middle Forks of the Salmon River may also have been losses, but we had no way of estimating the number.

With the likely losses in the Salmon River drainage, the minimum estimated prespawning loss rate of fish with radio transmitters in 1992 between Ice Harbor Dam and the tributaries or hatcheries was 37.4%, a smaller number than the estimate in 1991 (46%) and lower than the average loss calculated in a different way for prior years. Bjornn (1990) estimated that prespawning losses for wild spring and summer chinook salmon in the Snake River basin averaged 45% for the 1962-1968 period (only Ice Harbor Dam present), and 54% for the 1975-1988 period (all four dams in place). He estimated the number of wild spawners passing Ice Harbor Dam and compared that number with the number of spawners represented by the redds counted in the Snake River basin.

***Spring and summer chinook salmon distribution.***-A comparison of the fish found in each drainage versus the time they were tagged and released at Hood Park provides an estimate of the distribution of spring versus summer chinook salmon throughout the Snake River basin. As pointed out previously, 372 (66%) of the fish released at Hood Park with transmitters were released in April and May, and 195 (34%) were released in June and early July. Using the traditional cutoff date of 11 June, we would assume that most of the fish released in April, May, and early June were spring chinook salmon and those after 11 June and in July were summer chinook salmon. Of the 422 records of fish passing Lower Granite Dam, 303 (71.8%) of the fish had been released in April and May and 119 (28.2%) had been released in June and July (Figure 9), little change from the percentages at release, which is what we would expect unless there was a differential mortality for spring versus summer chinook salmon. Using 25 May as a more realistic cutoff date for 1992 (see Figure 3 for timing of salmon run at Ice Harbor Dam), 317 (55.9%) of the fish released with transmitters would have been spring and 250 (44.1%) summer chinook salmon, and the numbers of fish in the two runs passing Lower Granite Dam become 240 and 182, respectively. The correct cutoff date for 1992 could be as early as mid May and the date used will influence the estimates of spring versus summer chinook salmon entering each drainage.

Based on a 25 May cutoff date, 13 spring and 3 summer chinook salmon entered the Tucannon River in 1992.

Upstream from Lower Granite Dam, the distribution of spring and summer chinook salmon varied by tributary. Of the 63 fish with transmitters entering the Clearwater River in 1992, 58 were spring chinook salmon based on the 25 May cutoff date, and 5 were summer chinook salmon (Figure 9). Of the 330 salmon with transmitters heading up the Snake River and into tributaries upstream from Lewiston/Clarkston, 168 (51.0%) were from the spring run, based on the 25 May cutoff date, and 162 (49.0%) were fish of the summer run.

Within the Clearwater River basin, virtually all of the fish recorded in the Clearwater, Selway, and South Fork rivers and tributaries were spring chinook salmon in 1992 (Figure 10). The Lochsa River was the only stream that had a number of fish that might have been summer chinook salmon based on their latter half of May tagging dates. One of two chinook salmon entering Dworshak NFH in 1992 could also have been classified as a summer chinook based on the 14 June release date at Hood Park.

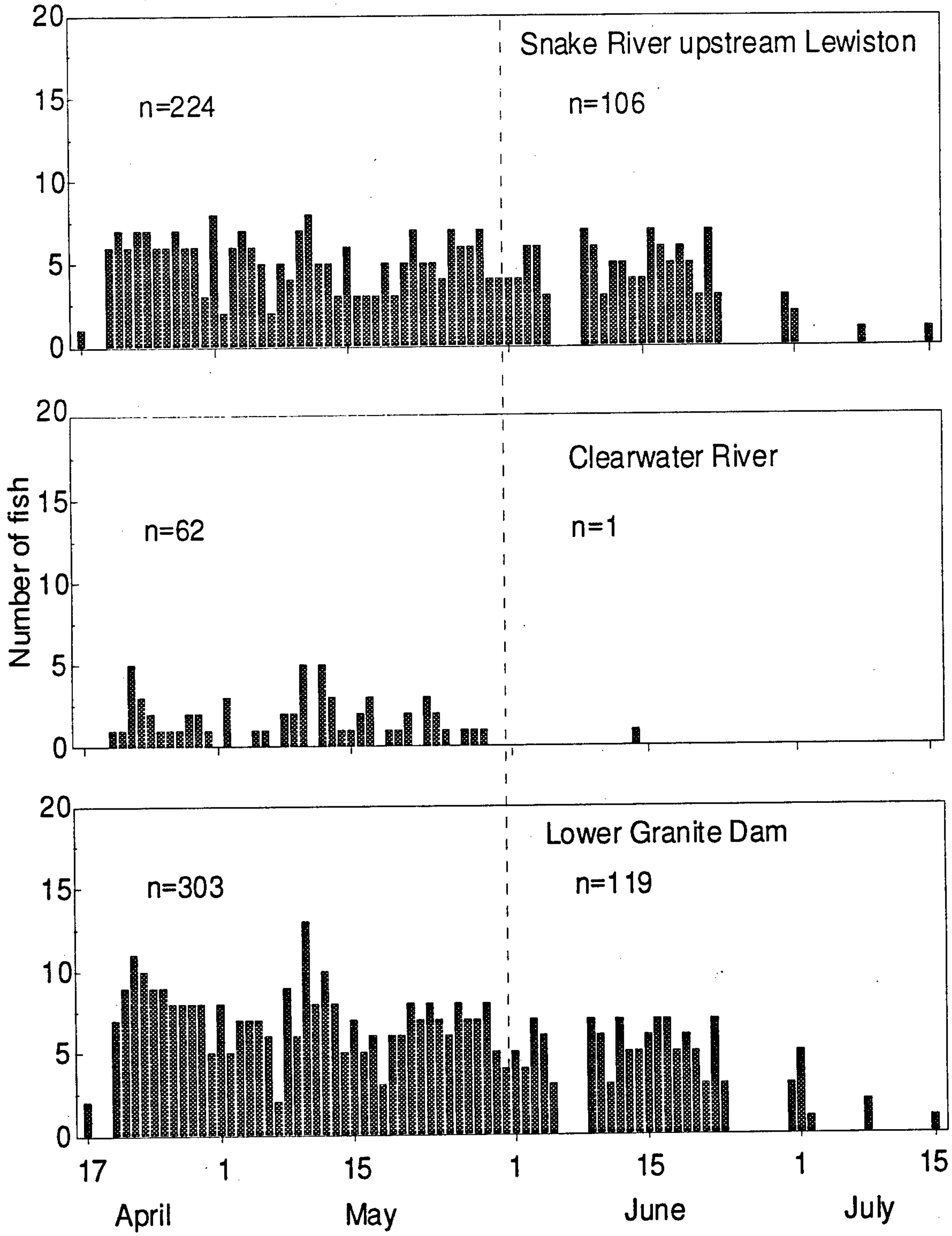



Figure 9. Frequency distribution of chinook salmon with transmitters passing Lower Granite Dam and entering the Clearwater and Snake River upstream from Lewiston based on time of tagging and release at Ice Harbor Dam in 1992.

In the Grande Ronde and Imnaha river basins, both spring and summer chinook salmon entered the rivers (Figure 11). All but about 8 of the 42 salmon entering the Grande Ronde River were spring chinook, and the remainder were classified as summer chinook salmon, based on a 25 May separation date. Only 1 of 20 chinook salmon entering the Imnaha River was classified as a spring chinook salmon, and the remainder were part of the summer run. Six spring and 3 summer chinook salmon were recaptured at Lookingglass Fish Hatchery or last recorded in Lookingglass Creek in 1992. Fish returning to the Wenaha, Wallowa, Minam and Lostine rivers and Bear and Catherine creeks consisted of 21 spring and 4 summer chinook salmon.

Of the 259 salmon with transmitters entering the Salmon River in 1992, 50% to 70% were spring chinook salmon and the remainder were summer-run fish depending on the cutoff date used to separate the two runs (Figure 12). Within the tributaries of the drainage, the proportion of spring- or summer-run fish varied widely. All but two of the 64 fish recorded in the Little Salmon River and its tributaries, including Rapid River Hatchery recaptures, were likely spring chinook salmon in 1992, based on a 25 May separation date. In other streams, the proportions of fish that might have been summer chinook salmon were larger.

In 1992, 112 chinook salmon with transmitters were recorded in the South Fork of the Salmon River drainage. Based on the time they were tagged at Ice Harbor Dam, half or more of the fish would be classed as belonging to the spring run if we used the 11 June cutoff date (Figure 12). Chinook salmon that returned to the South Fork drainage in 1992 were tagged from mid May through late June. If the salmon produced in the South Fork are almost exclusively summer-run fish, as has been concluded from prior evidence, then the timing of the summer run at Ice Harbor Dam in 1992 ran from early May through July, and there was evidence (nadir in fish counted) that the cutoff date between the two runs should be some time in the latter half of May rather than 11 June. Based on a 25 May cutoff date, the 112 salmon recorded in the South Fork of the Salmon River drainage would be classed as 22 spring and 90 summer chinook salmon (Figure 12). Johnson Creek had 1 spring and 7 summer chinook salmon, and the East Fork of the South Fork had 1 spring and 5 summer chinook salmon. The fish with transmitters in the Secesh River and Lake Creek consisted of 1 spring and 5 summer chinook salmon. Four of the 49 fish recorded or recaptured in the South Fork downstream from the weir near Knox Bridge would have been classed as spring chinook salmon, along with 12 of 40 fish recaptured at the weir. We believe most, if not all, of the fish that returned to the South Fork drainage

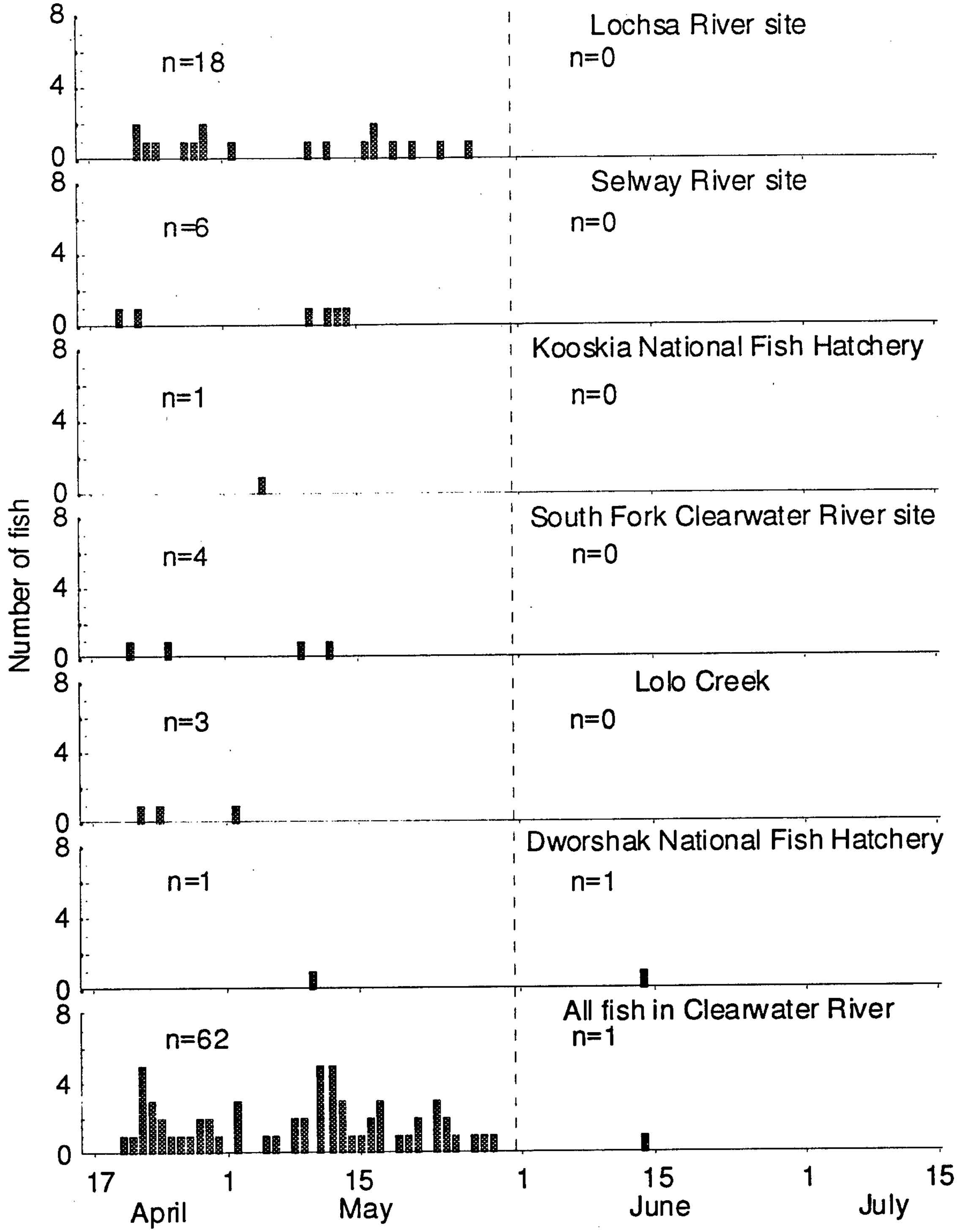



Figure 10. Frequency distribution of chinook salmon with transmitters entering the Clearwater River and tributaries and hatcheries within the basin based on time of tagging and release at Ice Harbor Dam in 1992.

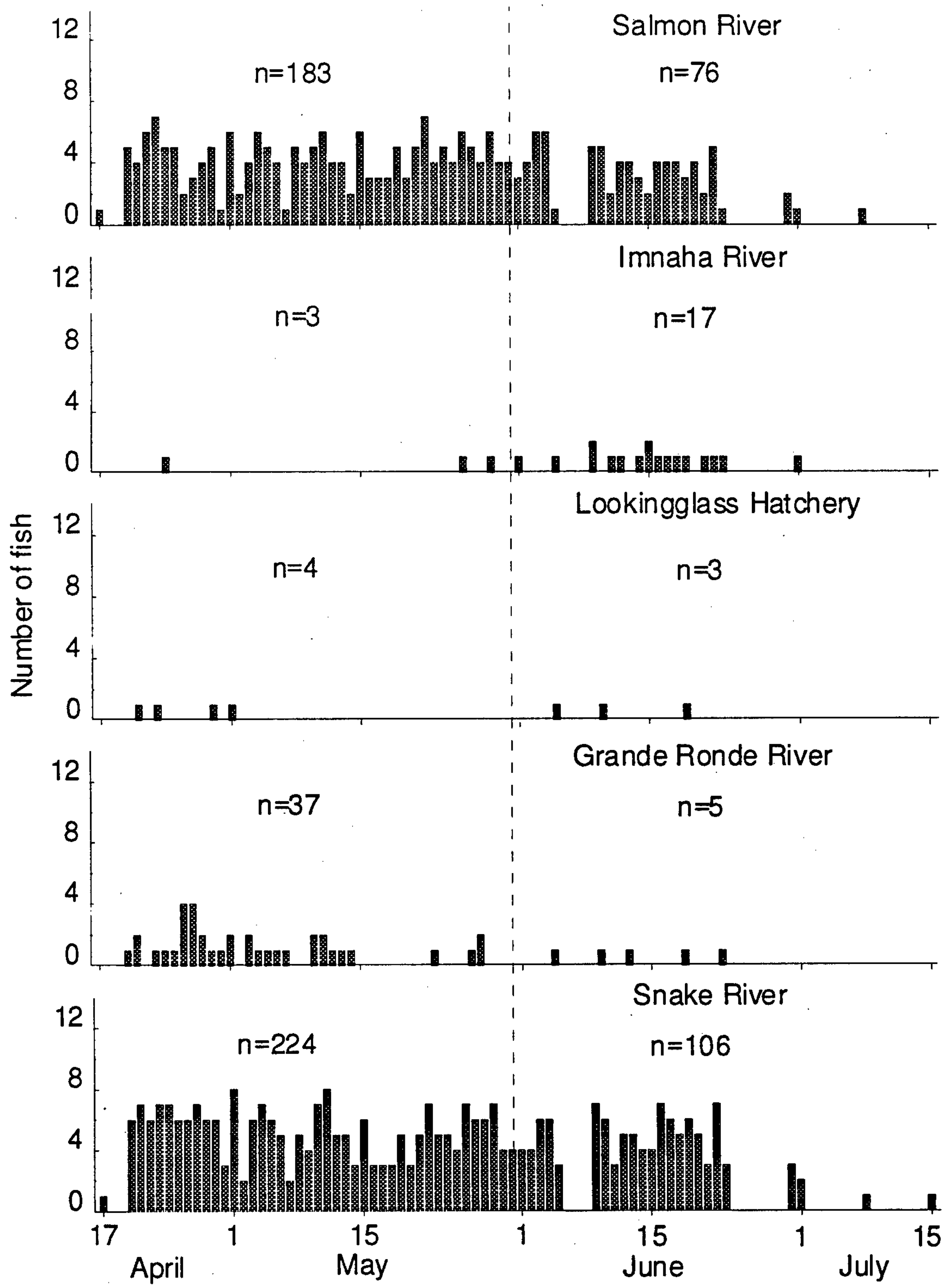



Figure 11. Frequency distribution of chinook salmon with transmitters entering the Snake River, tributaries, and hatcheries between Lewiston and the mouth of the Imnaha River based on time of tagging and release at Ice Harbor Dam in 1992.

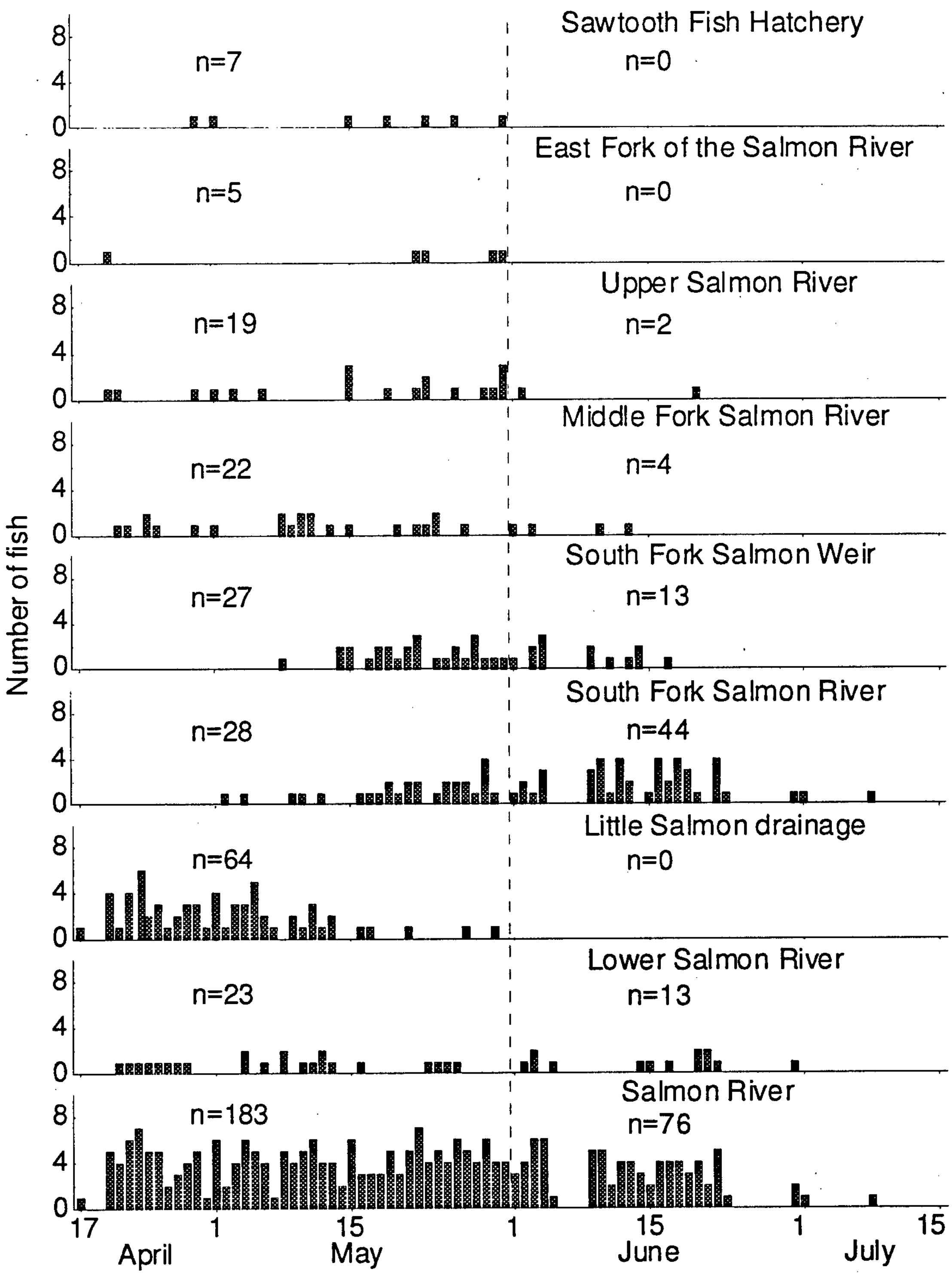



Figure 12. Frequency distribution of chinook salmon with transmitters entering the Salmon River, tributaries, and hatcheries based on time of tagging and release at Ice Harbor Dam in 1992.

in 1992 were summer chinook salmon and thus the numbers listed above as spring versus summer chinook salmon based on a 25 May cutoff date may still over estimate the number of spring chinook salmon.

A majority of the 26 salmon with transmitters that we believe entered the Middle Fork of the Salmon River drainage were spring chinook salmon in 1992 (Figure 12), as is usually the case, but 5 to 10 of the fish could have been from the summer run, depending on the cutoff date used.

Of the 21 fish last located in the Salmon River or its tributaries upstream from the receiver at North Fork in 1992, 13 would be classed as spring chinook salmon if we used the 25 May cutoff date (Figure 12). Fish were recorded or recaptured in the main Salmon, Lemhi, and East Fork of the Salmon rivers, and Herd Creek along with salmon returning to the Sawtooth Fish Hatchery weir.

***Transmitter status*** - Regurgitation of transmitters was monitored only during the time it took for tagged spring and summer chinook salmon to recover and exit freely from the recovery pen located in the Snake River at either Hood Park or Charbonneau Park. Eight transmitters (1.4%) were disgorged while fish were in the recovery tank. Transmitters were recovered, tagging records changed, and the regurgitated transmitters subsequently put in other fish. Sixteen of 376 chinook salmon checked at the Lower Granite adult trap (4.3%) had disgorged their transmitters after release at Hood Park. The regurgitation rate after release was higher than in 1991, as expected, because fish were held in the recovery tank in the Snake River for a short period of time in 1992. The last check on regurgitation rate was for the fish recaptured at weirs and hatcheries. Two of 143 chinook salmon (1.4%) recovered at hatcheries or from spawning grounds, with unquestioned data on transmitter status, did not have transmitters when they should have. Fish that regurgitated their transmitters after release were partially accounted for if they had the secondary tag used in 1992 (jaw tag) in place when they were recaptured at the Lower Granite adult trap, hatcheries, weirs in streams, and spawning grounds. A fish that regurgitated a transmitter in a non-traditional spawning area and then proceeded upstream to spawn undetected, would be counted as a loss, if the signal from the regurgitated transmitter was picked up while mobile tracking. Such fish, if properly accounted for, would not reduce the loss rate more than 3-5%, in our opinion.

One method to assess transmitter reliability instituted in 1992 involved placing an SRX-400 Receiver and a coaxial cable underwater antenna at the Lower Granite trap. After the

27 May 92 installation date, each radio-tagged fish arriving at the trap was checked for transmitter operation. The Lower Granite trap receiver was installed after it was discovered that some transmitters were known to have failed prematurely and probably had already passed the trap. Four non-working transmitters were pulled from chinook salmon at the Lower Granite trap after installation of the receiver, and transmitter returns to the University of Idaho from recaptured fish revealed an additional six faulty transmitters. Of these six transmitters, three were working at least until the fish arrived near the recapture location, one transmitter quit working below Ice Harbor Dam (no records after the tailrace Ice Harbor site), one quit working at Little Goose Dam, and one never logged and was returned inoperable. Of these three bad transmitters, two were placed in fish in April, and one on 16 May. The transmitter placed in a spring chinook salmon on 16 May quit working at Little Goose Dam, so all three fish were probably already past the Lower Granite trap before the 27 May receiver installation date.

***Migration rates.***-The median time spring and summer chinook salmon took to pass the four lower Snake River dams in 1992 varied from a high of 1.3 d (2.3 mean d) at Lower Granite Dam to a low of 0.2 d (0.6 d mean)at Little Goose Dam (Table 2). Time required for a fish to pass a dam was measured as the lapsed time from the last record of a fish at the tailrace receivers to the last record from the same fish on a receiver/antenna at the top of the ladders. The distribution of passage times was more spread out at Ice Harbor and Lower Granite dams compared to the other two dams (Figure 13), and reflected the fact that many fish took several days to enter the fishway and pass up through the ladders. Nearly 5% (20) of the fish passing Ice Harbor Dam took more than 10 d to move upstream, while 3.4% of 350 chinook salmon passing Lower Granite Dam took 10 d or more; of 429 fish passing Lower Monumental Dam in 1992, none took longer than 3.8 d, and only one of 436 fish passing Little Goose Dam took over 10 d. Fish may have taken longer to pass Ice Harbor and Lower Granite dams because of the traps operated in the south ladders of both dams, or perhaps because of confusion at being taken back downstream to Hood Park for tagging and release. The relatively low, similar median days for passage at Lower Monumental and Little Goose dams is an indication that the nighttime spill for smolts at Lower Monumental Dam in 1992 had little, if any, effect on upstream migrating adults.

Improved siting of receivers and antennas within the fishways at all four lower Snake River dams in 1992 gave us a better idea of where salmon were spending their time while passing each dam. However, analysis of Digital Spectrum Processor (DSP) data collected during a test of these units at Lower Granite Dam in the late summer and fall of 1992, revealed a much clearer and accurate picture of migratory movements within the collection channel and at entrances than

had been obtained before. Although our setup in spring of 1992 gave us more complete records of fish movements at the dams than in 1991, the use of DSP units purchased and installed in the spring of 1993 at all dams, will result in further improvements in the movement information and made previous monitoring methods within collection channels largely obsolete.

Table 2. Mean and median number of days to migrate from the Hood Park release site to the tailrace of Ice Harbor Dam and the days to pass each of the four dams in the Lower Snake River for spring and summer chinook salmon in 1992.

| | Number of fish | Mean number of days | Range of days | Confidence intervals (95%) | Median number of days |
|---|---|---|---|---|---|
| Hood Park to Ice Harbor | 486 | 2.2 | 0.12-28.1 | 0.0-40.5 | 0.8 |
| Past a dam | | | | | |
| Ice Harbor | 440 | 2.4 | 0.00-30.2 | 0.00-8.8 | 1.2 |
| Lower Monumental | 429 | 0.6 | 0.1-3.8 | 0.00-1.6 | 0.4 |
| Little Goose | 436 | 0.6 | 0.03-15.6 | 0.00-2.6 | 0.2 |
| Lower Granite | 350 | 2.3 | 0.16-24.1 | 0.0-7.9 | 1.3 |

Spring and summer chinook salmon migration through the Snake River reservoirs in 1992 was more variable than in 1991, even though both years had relatively low, clear runoff flows (Table 3). Fish migrated from the Ice Harbor Dam forebay to the Lower Monumental Dam tailrace in 1.0 d on average (63.1 km/d), through the Lower Monumental pool in 2.1 d (24.8 km/d), through the Little Goose pool in 2.5 d (28.8 km/d), and through the Lower Granite pool to the lower Clearwater River and Snake River receiver sites in 3.1 and 1.5 d (33.6 and 47.5 km/d), respectively. In 1991, migration rates through the reservoirs, based on mean days to pass, were all higher than 47.5 km/d. The median number of days that chinook salmon took to pass through the reservoirs was slightly smaller than the mean days (Table 3), an indication of distributions skewed to the right (Figure 14). Passage rates based on median days were slightly higher than those based on mean days, but still not equal to rates observed in 1991.

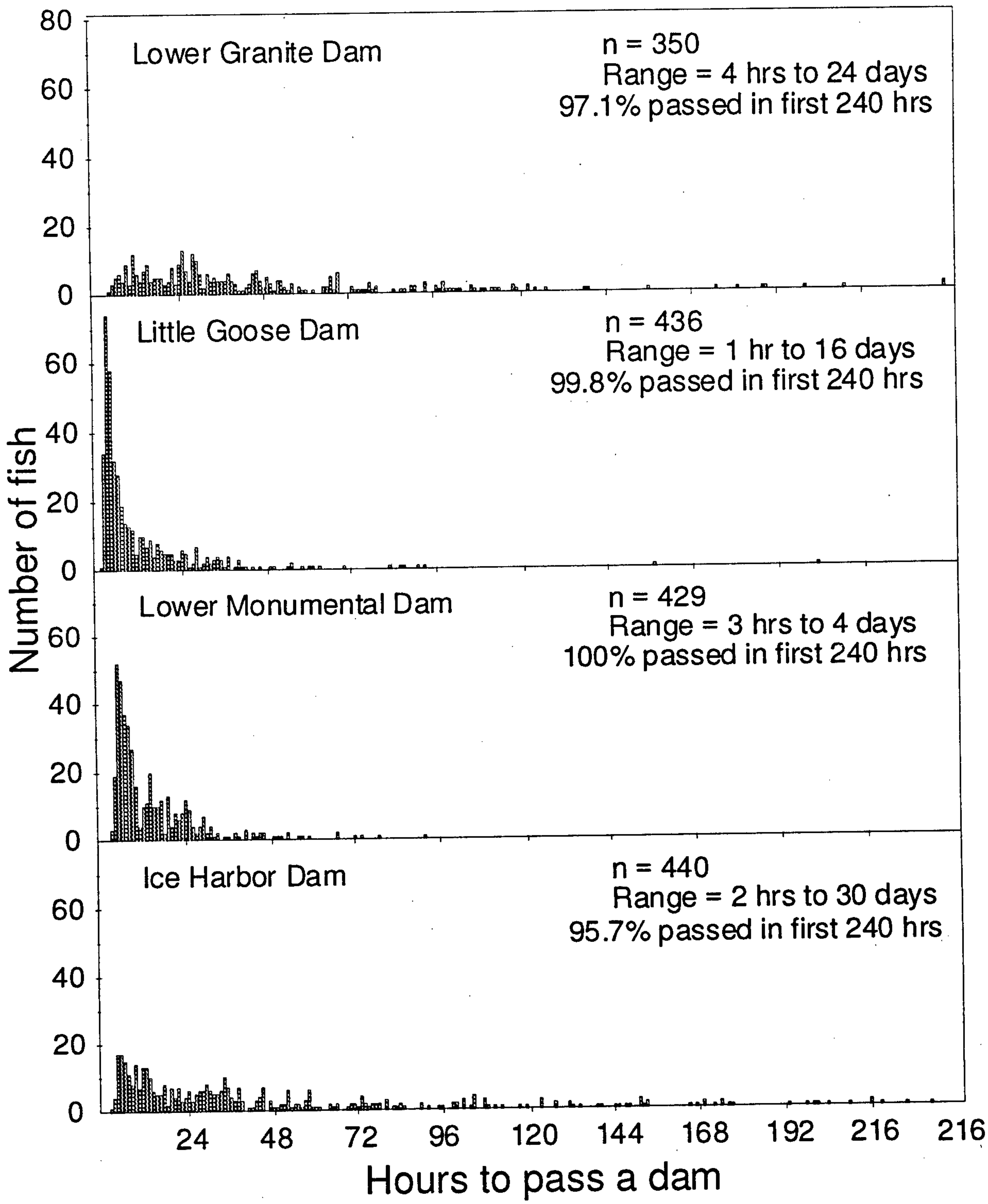



Figure 13. Frequency distribution of time to pass the four dams in the lower Snake River from the tailrace to the top of the ladder by spring and summer chinook salmon with radio transmitters in 1992.

Table 3. Migration rates of chinook salmon with transmitters through reservoirs and in free flowing sections of river in 1992 as measured by fish recorded at receivers at the dams and at fixed-location sites in the rivers.

| Section of river | Number of fish | Mean travel rates | | Confidence interval | | Median travel rates | |
|---|---|---|---|---|---|---|---|
| | | Days | Km/day | Days | Km/day | Days | Km/day |
| Through reservoirs | | | | | | | |
| Ice Harbor to Lower Monumental dams | 432 | 1.0 | 63.1 | (0.0-3.2) | (26.4-99.8) | 0.8 | 64.3 |
| Lower Monumental to Little Goose dams | 423 | 2.1 | 24.8 | (0.1-3.9) | (7.4-39.2) | 1.9 | 23.7 |
| Little Goose to Lower Granite dams | 408 | 2.5 | 28.8 | (0.0-7.2) | (9.7-47.9) | 2.1 | 27.4 |
| Lower Granite Dam to Clearwater River site | 53 | 3.1 | 33.6 | (0.0-10.1) | (0.0-72.1) | 1.9 | 30.2 |
| Lower Granite Dam to Snake River site | 316 | 1.5 | 47.5 | (0.0-3.8) | (22.2-83.7) | 1.2 | 55.6 |
| Through rivers | | | | | | | |
| Snake River to Grande Ronde River sites | 27 | 2.0 | 34.9 | (0.0-8.2) | (2.2-67.7) | 0.9 | 38.4 |
| Snake River to Lower Salmon River sites | 228 | 7.4 | 30.3 | (1.9-13.0) | (13.2-47.5) | 6.6 | 30.5 |
| Snake River to Imnaha River sites | 20 | 9.2 | 12.7 | (0.0-18.4) | (1.5-23.8) | 7.2 | 12.8 |
| Lower Salmon to South Fork Salmon sites | 103 | 9.9 | 15.1 | (3.4-16.4) | (6.1-24.2) | 9.4 | 14.6 |
| Lower Salmon to Middle Fork Salmon sites | 40 | 7.7 | 26.0 | (2.1-13.3) | (11.6-40.4) | 7.0 | 26.0 |
| Lower Salmon to upper Salmon sites | 17 | 9.6 | 26.8 | (5.2-14.0) | (15.4-38.1) | 8.9 | 27.4 |
| Lower Clearwater to Lochsa sites | 18 | 17.7 | 14.8 | (0.0-61.2) | (0.0-36.4) | 12.0 | 12.5 |

The average rates of passage of fish through the four lower Snake River dams and reservoirs were 12.0 d at 23.1 km/d for fish returning to the Snake River, and 14.6 d at 59 km/d for fish entering the Clearwater River. The migration rate distributions tended to be skewed to the right with a few fish taking a relatively long time to migrate from dam to dam, but most of the fish passed between dams in less than 1 d (Figure 14). Migration rates of fish through the Lower Granite pool appeared to be slower than through the three downstream pools, but the Lower Granite pool reach includes a few kilometers of the Clearwater (receiver at river km 7.5) and Snake (receiver at river km 237.1) rivers upstream from the end of the pool. Turbidities may have been higher in the Lower Granite pool and in both of the rivers periodically during the migration season and may have been a factor in the slower migration rate.

Migration rates of fish in the free-flowing sections of the Snake, Clearwater, and Salmon rivers were slower than those of fish in the reservoirs (Table 3). In the free-flowing rivers, salmon migrated at mean rates of 13 to 35 km/d versus an average rate of 39 km/d through the three reservoirs between dams, and 41 km/d when the Lower Granite Dam to the lower Clearwater River and Snake River fixed receiver sites were included in the average. Factors that may have contributed to the slower rates of migration in the free-flowing rivers include higher velocities and turbidities in the rivers than in the reservoirs, and, in some reaches, a slowing of migration as fish approached their natal stream.

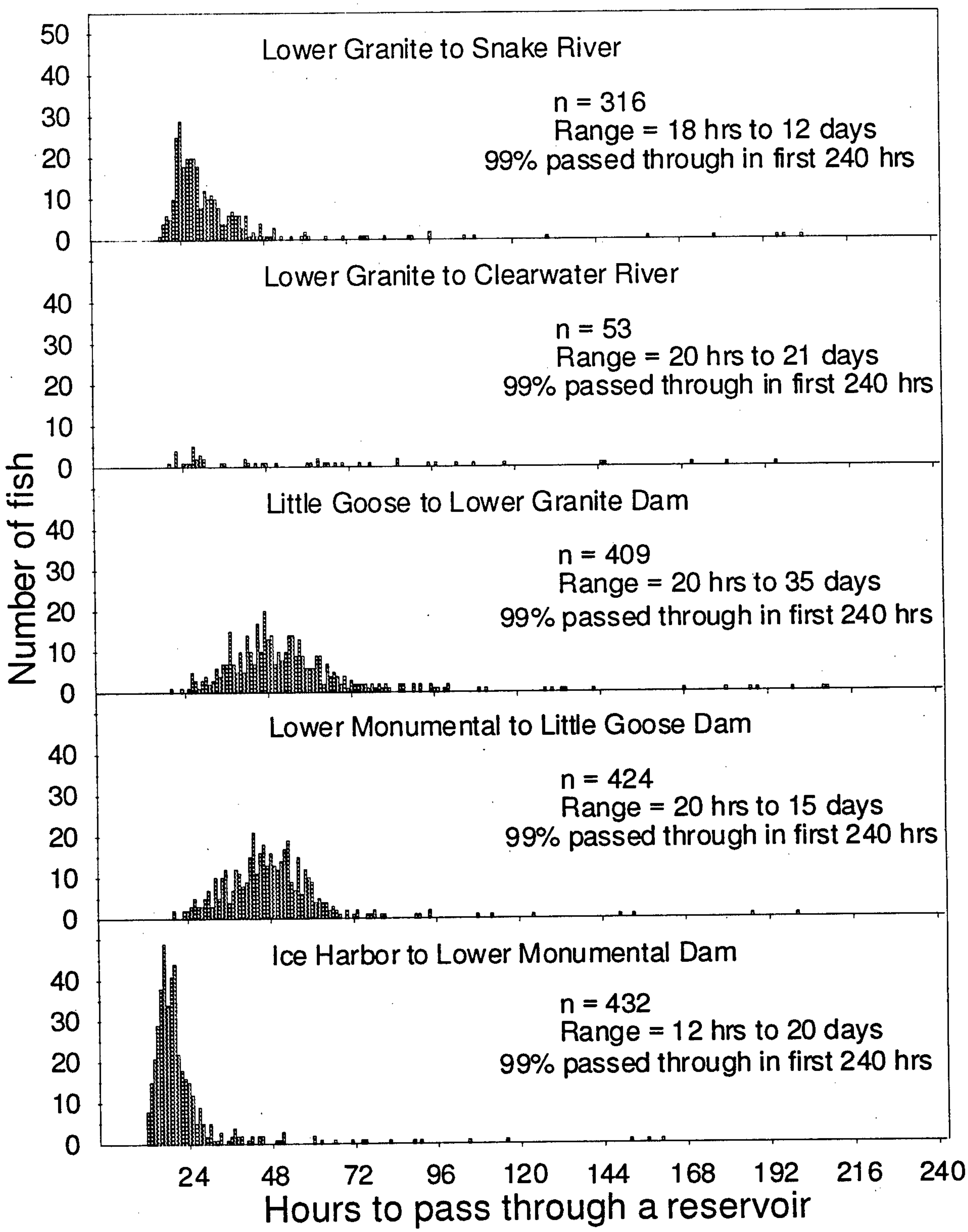



Figure 14. Frequency distribution of time to pass through the four reservoirs in the lower Snake River by spring and summer chinook salmon with radio transmitters in 1992.

## Steelhead - Migration Rates, Passage Success, and Distribution

### *Methods - Steelhead Tagged in 1991*

Migration rates and passage at the dams and into the tributaries of the Snake River were assessed for steelhead tagged in 1991 in a similar manner to that described for chinook salmon. Receivers set up to monitor chinook salmon movements at the dams and mouths of the major tributaries were also used to monitor steelhead movements.

Capture and outfitting steelhead with transmitters at Ice Harbor Dam began in early July of 1991 in an attempt to evaluate some in-river construction near Lower Granite Dam. During July, 210 steelhead were captured, outfitted with transmitters, jaw tagged, and released at Hood Park (Figure 15). The pile driving was completed more quickly than anticipated so we were unable to evaluate the effect of pile driving on steelhead movements. The fish released in July were nonetheless tracked and provided information on movements of steelhead from the early segment of the run into the Snake River.

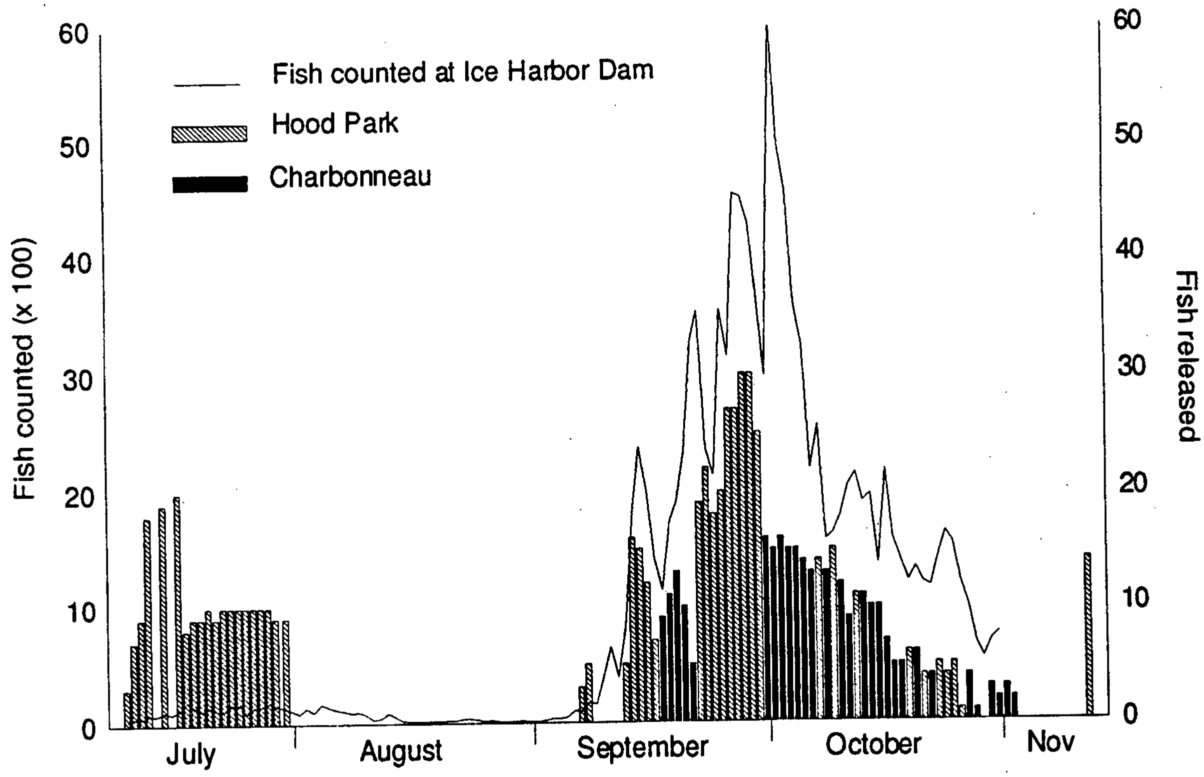



Figure 15. Daily counts of steelhead at Ice Harbor Dam and numbers trapped at the dam, outfitted with transmitters (bars), and released at Hood Park or Charbonneau campgrounds in 1991.

Water temperatures in the river and the fishways at the dams exceeded 20°C during the latter part of July, August, and early September (Bjornn et al. 1992). For that reason, few fish entered the Snake River until mid September and no more steelhead were trapped and released with transmitters until water temperatures declined.

During September, October, and November, another 524 fish were released with transmitters at Hood Park and Charbonneau Campground (Figure 15), with the latter located 1.7 km upstream from the dam. Steelhead were released upstream from the dam to evaluate the effect of the Hood Park release site on subsequent migrations back into the Columbia River or back up to Ice Harbor Dam as they continued up the Snake River.

A major difference between the steelhead and chinook salmon portions of the telemetry work, was the presence of an active fishery in most of the Snake River basin where steelhead migrated. Anglers captured many of the steelhead with transmitters and many of the transmitters and jaw tags were turned in to provide information and get the $5 reward.

### *Results - Steelhead Tagged in 1991*

***Passage success.***-The steelhead that were monitored as they migrated through the lower Snake River were divided into three groups based on time and location of release. Fish released at Hood Park in July were separated from those released at Hood Park and Charbonneau campgrounds in the fall. Eighty-five percent of the steelhead released in July were classified as hatchery in origin (had an adipose fin clip), versus 55% of those released in the fall at Hood Park, and 77% of those released in the fall at Charbonneau Campground (Table 4).

Of the 210 steelhead released at Hood Park with transmitters in July of 1991, 89 were recorded as entering the tailrace at Ice Harbor Dam, 54 at Lower Monumental Dam, 38 at Little Goose Dam, and 18 at Lower Granite Dam (Figure 16). Thirty-seven of the 210 steelhead released in July were recaptured at the Lower Granite trap, only 1 was recorded going into the Clearwater River, and 16 were recorded migrating up the Snake River near Asotin (Table 4). Fourty-two percent of the fish released in July were recorded as having returned back upstream to the Ice Harbor Dam tailrace, 7% were recorded exiting the top of the ladder and 18% were recaptured in the trap at Lower Granite Dam.

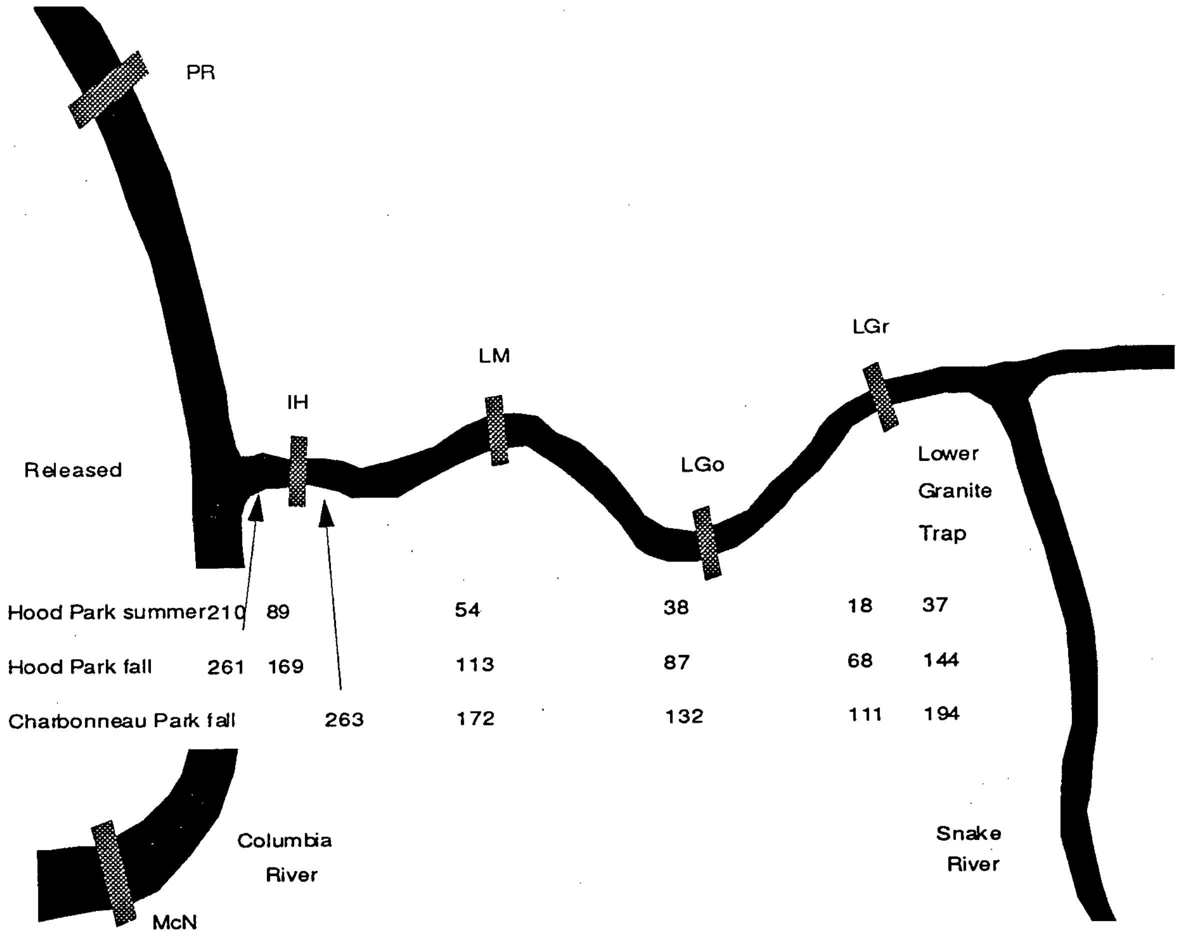



Figure 16. Map of the lower Snake River with the number of steelhead released at Hood Park or Charbonneau campgrounds in July and the fall of 1991, and the number of fish recorded on receivers in the tailrace of each of the dams and recaptured at the Lower Granite trap in the fall of 1991 through spring of 1992.

Of the 261 steelhead released at Hood Park with transmitters in the fall of 1991, 169 were recorded as entering the tailrace at Ice Harbor Dam, 113 at Lower Monumental Dam, 87 at Little Goose Dam, and 68 at Lower Granite Dam (Figure 16). At the Lower Granite adult trap, 144 of the 261 steelhead released in the fall at Hood Park were recaptured, 40 were recorded going into the Clearwater River, and 58 were recorded migrating up the Snake River near Asotin (Table 4). Sixty-five percent of the 261 fish released at Hood Park in the fall were recorded back up in the Ice Harbor tailrace, 35% were recorded exiting the ladder and 55% were recaptured in the trap at Lower Granite Dam.

A higher percentage of the steelhead released at Charbonneau Campground upstream from Ice Harbor Dam passed the remainder of the dams in the Lower Snake River than

Table 4. The number of steelhead recorded or recaptured at sites in the lower Snake River for groups released at Hood Park in July and in the fall, and for fish released at Charbonneau Campground in the fall of 1991.

| | Released at Hood Park in July Number released, recorded, recaptured | | | Released at Hood Park in fall Number released, recorded, recaptured | | | Released at Charbonneau in fall Number released, recorded, or recaptured | | |
|---|---|---|---|---|---|---|---|---|---|
| Location/Activity | Total | Wild | Hatchery | Total | Wild | Hatchery | Total | Wild | Hatchery |
| Fish released | 210 | 31 | 179 | 261 | 117 | 144 | 263 | 60 | 203 |
| Ice Harbor Dam receivers | | | | | | | | | |
| Tailrace | 89 | 17 | 72 | 169 | 73 | 96 | 0 | 0 | 0 |
| Top of ladder | 68 | 11 | 57 | 137 | 63 | 73 | 1 | 0 | 1 |
| Lower Monumental Dam receivers | | | | | | | | | |
| Tailrace | 54 | 9 | 45 | 113 | 47 | 65 | 172 | 44 | 128 |
| Top of ladder | 55 | 10 | 45 | 119 | 47 | 71 | 155 | 39 | 116 |
| Little Goose Dam receivers | | | | | | | | | |
| Tailrace | 38 | 9 | 23 | 87 | 39 | 47 | 132 | 33 | 99 |
| Top of ladder | 14 | 3 | 11 | 77 | 31 | 45 | 112 | 25 | 87 |
| Lower Granite Dam receivers | | | | | | | | | |
| Tailrace | 18 | 3 | 15 | 68 | 24 | 44 | 111 | 27 | 84 |
| Top of ladder | 15 | 5 | 10 | 91 | 41 | 49 | 136 | 32 | 104 |
| Lower Granite Trap | 37 | 7 | 30 | 144 | 62 | 82 | 194 | 44 | 150 |
| Upstream from Lower Granite Dam | | | | | | | | | |
| Clearwater R. | 1 | 1 | 0 | 40 | 15 | 25 | 51 | 10 | 41 |
| Snake R. | 16 | 4 | 12 | 58 | 33 | 25 | 63 | 23 | 40 |

either group of fish released at Hood Park downstream from the dam. Of the 263 steelhead released at Charbonneau Campground in the fall of 1991, 172 were recorded as entering the tailrace at Lower Monumental Dam, 132 at Little Goose Dam, and 111 at Lower Granite Dam (Table 4). Seventy-three percent (194) of the fish released at Charbonneau were recaptured at the Lower Granite adult trap, 52% were recorded exiting the ladder, 51 fish were recorded going into the Clearwater River, and 63 fish were recorded migrating up the Snake River near Asotin.

A lower percentage of steelhead released near Ice Harbor Dam in 1991 were recorded as passing the upstream dams when compared with chinook salmon (about 87% of the salmon passed Lower Granite Dam in 1991 and 81% in 1992). For steelhead, the percentages of fish released that were recaptured at the Lower Granite trap were 18% for those released at Hood Park in July, 55% for those released at Hood Park in the fall of 1991, and 73% for those released upstream from Ice Harbor Dam in the fall. Removal of fish by the fishery downstream from Lower Granite Dam is a partial explanation for the reduced proportions passing upstream; about 8% of the steelhead with transmitters were reported caught from the lower Snake River by anglers. In addition, some steelhead spend the winter in the downstream reservoirs and the losses before passage may be higher than for chinook salmon because salmon spend relatively little time in the lower Snake River. The fish released in July must migrate upstream in a river with temperatures near lethal levels. And lastly, there is evidence that hauling steelhead back downstream and requiring them to pass over Ice Harbor Dam a second time reduces the proportion passing upstream. The proportion of steelhead released at Charbonneau Campground with spaghetti-loop tags in the fall for the zero-flow test that passed over Lower Granite Dam was higher than for either group of fish released at Hood Park, and similar to the rate for fish with transmitters released upstream from the dam.

Similar proportions of the steelhead classified as wild or hatchery and released in 1991 migrated upstream past the dams, but a smaller proportion of the hatchery fish than wild fish were recorded or recaptured upstream from Lower Granite Dam (Table 5). Only one of the steelhead released in July entered the Clearwater River versus 16 that were recorded in the Snake River near Asotin (Table 4). For the steelhead released in the fall, both hatchery and wild fish entered the Clearwater and Snake rivers upstream from Lewiston, with the numbers reflecting, perhaps, the proportions of hatchery and naturally produced fish in the various drainages.

Table 5. Number of wild and hatchery steelhead released at Hood Park and Charbonneau campgrounds in July and fall of 1991, and the number recorded or recaptured at various upstream locations.

| | Released at: | | | | | |
|---|---|---|---|---|---|---|
| | Hood Park - July | | Hood Park - fall | | Charbonneau - fall | |
| | Wild | Hatchery | Wild | Hatchery | Wild | Hatchery |
| Fish released | 31 | 179 | 117 | 144 | 60 | 203 |
| Percent recorded at: | | | | | | |
| Ice Harbor tailrace | 55 | 40 | 62 | 67 | -- | --- |
| Lower Granite tailrace | 10 | 8 | 21 | 31 | 45 | 41 |
| Lower Granite trap | 23 | 17 | 53 | 57 | 73 | 74 |
| Upstream from Lower Granite | 16 | 7 | 41 | 35 | 55 | 40 |

***Migration rates.***-The median time for steelhead released in the fall to pass the four lower Snake River dams in 1991 ranged from a high of 1.2 d at Lower Granite Dam to a low of 0.4 d at Lower Monumental Dam (Table 6). Median passage times for steelhead released in July of 1991 were more variable (0.3 to 1.5 d) than those of fish released in the fall. The above listed rates were for fish that crossed over Lower Granite Dam before 31 December 1991, and represent fish that were intent on migrating through the lower Snake River in the fall. For fish that did not pass Lower Granite Dam until after 31 December (mostly in March and April of 1992), the time to pass a dam was much more variable and extended (up to a mean of 64 d and median of 44 d ) than for fall migrating fish (Table 7).

As with chinook salmon in 1991 and 1992, median passage time for steelhead that migrated through the lower Snake River in the fall of 1991 was higher at Ice Harbor and Lower Granite dams, than at Lower Monumental and Little Goose dams. Time required for a fish to pass a dam was measured as the lapsed time from the last record of a fish at the tailrace receivers to the last record from the same fish on a receiver/antenna at the top of the ladders.

The distribution of passage times was similar at the four lower Snake River dams for steelhead released at Hood Park in the fall and migrating past Lower Granite Dam in the fall (Figure 17), with a high percentage of the fish passing within 10 d, and most passing within 48 hours. About 13% of the fish passing Ice Harbor Dam took more than 10 d to cross the dam, but only 3% of 351 chinook salmon crossing Lower Granite took 10 d or more. All of the 86 steelhead in the group passing over Lower Monumental Dam in 1991 did so in about 2 d. Fish may have taken longer to pass Ice Harbor and Lower Granite

dams because of the traps operated in the south ladders of both dams, or perhaps because of confusion at being taken back downstream to Hood Park for tagging and release. Improved siting of receivers and antennas within the fishways at all four lower Snake River dams in 1992, plus the use of Digital Spectrum Processors (DSP) at

Table 6. Mean and median number of days for steelhead to migrate from the Hood Park (HPK) release site to the tailrace of Ice Harbor Dam and from the Charbonneau Park (CHAR) release site to the tailrace of Lower Monumental Dam and the days to pass each of the four dams in the lower Snake River for fish passing Lower Granite Dam before 31 December 1991.

| | Number of fish | Mean number of days | Range of days | Median number of days |
|---|---|---|---|---|
| Hood Park (HPK) to Ice Harbor Dam | | | | |
| July released fish | 88 | 39.9 | 0.3 - 131.9 | 48.4 |
| Fall released fish | 151 | 9.4 | 0.1 - 75.5 | 2.8 |
| Charbonneau Park (CHAR) to Lower Monumental Dam | | | | |
| Fall released fish | 162 | 5.1 | 0.8 - 54.6 | 2.2 |
| Past a Dam | | | | |
| Ice Harbor | | | | |
| HPK July released fish | 47 | 4.1 | 0.05 - 76.6 | 1.2 |
| HPK fall released fish | 108 | 5.0 | 0.1 - 69.0 | 0.9 |
| Lower Monumental | | | | |
| HPK July released fish | 44 | 0.8 | 0.01 - 69.0 | 0.3 |
| HPK fall released fish | 86 | 0.6 | 0.1 - 2.1 | 0.4 |
| CHAR fall released fish | 132 | 1.1 | 0.1 - 14.1 | 0.6 |
| Little Goose | | | | |
| HPK July released fish | 9 | 13.0 | 0.15 - 92.2 | 0.3 |
| HPK fall released fish | 39 | 1.9 | 0.1 - 17.1 | 0.9 |
| CHAR fall released fish | 73 | 1.0 | 0.1 - 11.8 | 0.5 |
| Lower Granite | | | | |
| HPK July released fish | 10 | 3.3 | 0.7 - 9.2 | 1.5 |
| HPK fall released fish | 38 | 2.9 | 0.2 - 42.3 | 1.2 |
| CHAR fall released fish | 87 | 1.9 | 0.2 - 20.7 | 1.0 |

Table 7. Mean and median number of days for steelhead to migrate from the Hood Park release site to the tailrace of Ice Harbor Dam and from the Charbonneau Park release site to the tailrace of Lower Monumental Dam and the days to pass each of the four dams in the Lower Snake River for fish passing Lower Granite Dam after 31 December 1991.

| | Number of fish | Mean number of days | Range of days | Median number of days |
|---|---|---|---|---|
| Hood Park (HPK) to Ice Harbor Dam | | | | |
| July released fish | 1 | 117.4 | | |
| Fall released fish | 18 | 52.6 | 0.4-196 | 26.9 |
| Charbonneau Park (CHAR) to Lower Monumental Dam | | | | |
| Fall released fish | 10 | 14.9 | 2.6-49.1 | 5.8 |
| Past a Dam | | | | |
| Ice Harbor | | | | |
| HPK July released fish | 1 | 4.2 | | |
| HPK fall released fish | 12 | 17.9 | 0.2-106 | 0.8 |
| Lower Monumental | | | | |
| HPK July released fish | 1 | 0.9 | | |
| HPK fall released fish | 13 | 2.4 | 0.02-12.7 | 0.3 |
| CHAR fall released fish | 8 | 44.9 | 0.4-104.7 | 44.0 |
| Little Goose | | | | |
| HPK July released fish | 1 | 24.5 | | |
| HPK fall released fish | 11 | 31.0 | 0.6-117.7 | 7.9 |
| CHAR fall released fish | 8 | 24.5 | 0.2-119.1 | 3.8 |
| Lower Granite | | | | |
| HPK July released fish | 0 | | | |
| HPK fall released fish | 7 | 63.6 | 6.1-143.2 | 18.5 |
| CHAR fall released fish | 4 | 32.0 | 3.2-84.5 | 20.1 |

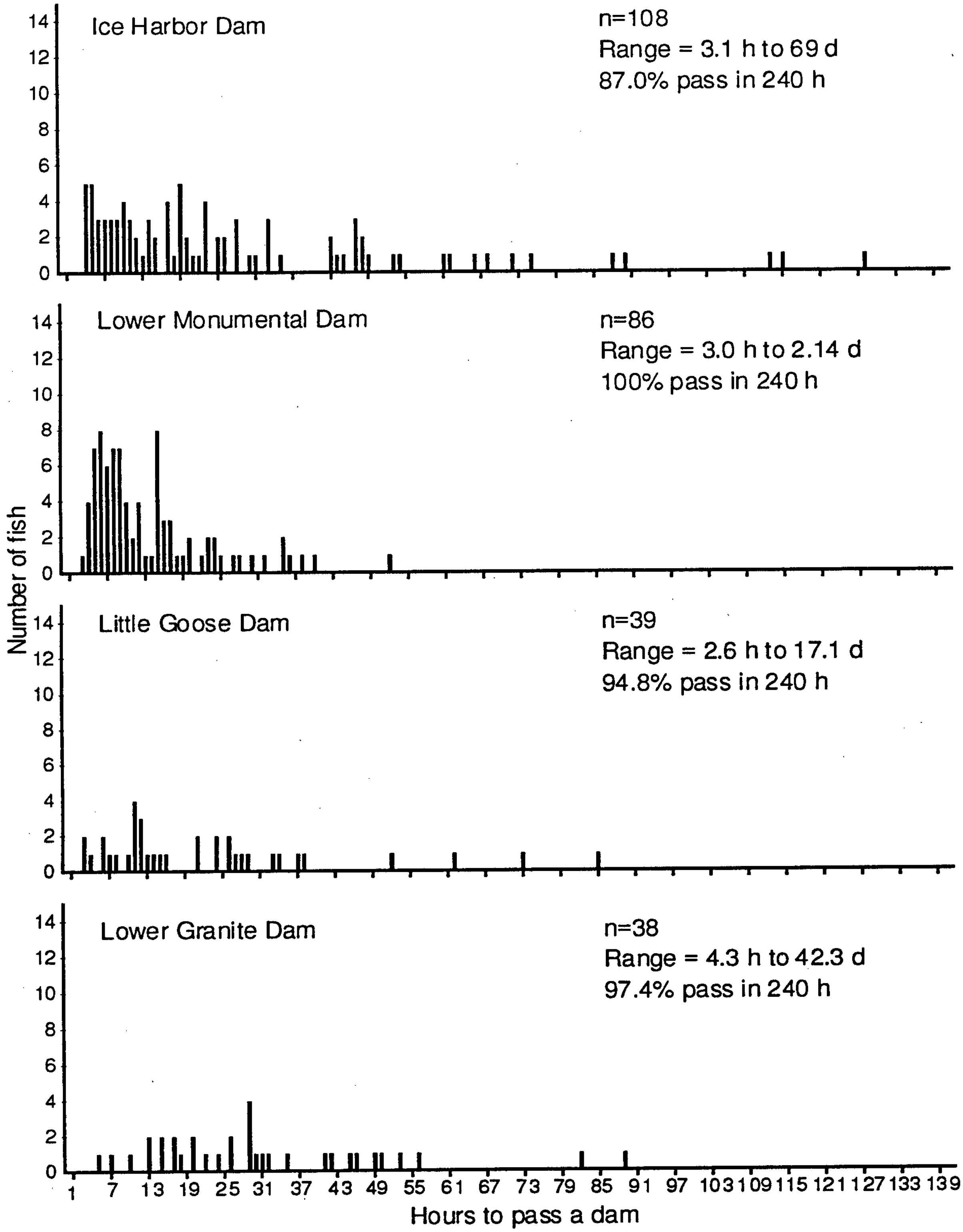



Figure 17. Frequency distribution of the time for steelhead to pass dams in the lower Snake River in 1991. Steelhead released at Hood Park in the fall that crossed over Lower Granite Dam before 31 December 1991.

Lower Granite Dam in the late summer and fall of 1992, provided a more complete and accurate picture of migratory movements within collection channels and at entrances to collection channels (reported in a later section).

The distribution of passage times at three Snake River dams for steelhead released at Charbonneau Campground in the fall and migrating past Lower Granite Dam in the fall was similar with most fish crossing the dams within 48 hours (Figure 18). Fewer than 4% of the fish took more than 10 d to cross any of the dams. Steelhead released in July of 1991 and migrating past Lower Granite Dam before 31 December passed over the dams mostly within 48 hours, but with a wider spread of the distribution at Ice Harbor Dam (Figure 19).

The migration of steelhead through the lower Snake River reservoirs in 1991 was generally about half the rate of that for chinook salmon. Migration rates through the reservoirs of steelhead that migrated over Lower Granite Dam before 31 December, ranged up to 25 km/d based on mean days for passage and 40 km/d for median days (Table 8), versus rates for chinook salmon of up to 60 km/d. Fish that migrated from Lower Granite Dam forebay into the Clearwater River had a slower migration rate than fish that migrated into the Snake River near Asotin. Steelhead that did not cross Lower Granite Dam until after 31 December had somewhat higher migration rates through some of the reservoirs (Table 9), but the sample sizes were small.

Migration rates of steelhead in the free-flowing sections of the Snake, Clearwater, and Salmon rivers were slower than those in the reservoirs (Table 8). In the free-flowing rivers, steelhead migrated at mean rates of about 10 or fewer km/d, versus rates in the reservoirs of 20-30 km/d. The slower migration rates in the rivers is mostly due to the fact that steelhead cease migrating in the late fall and spend the winter in the rivers. Many of the fish migrated out of Lower Granite Reservoir and into the Snake, lower Clearwater, and lower Salmon rivers where they ceased migrating in November or December and did not resume upstream movements until the next spring.

Most steelhead migrated through the individual lower Snake River reservoirs in less than 10 d, especially those steelhead that migrated past Lower Granite Dam before 31 December 1991. Steelhead released in the fall at Hood Park had a wider distribution of days to migrate through the Ice Harbor pool (Figure 20) than fish released at Charbonneau Campground in fall (Figure 21) or at Hood Park in July (Figure 22). Otherwise, the modal groups were fish that moved through the reservoirs in two d. A few fish stayed in a single pool several months.

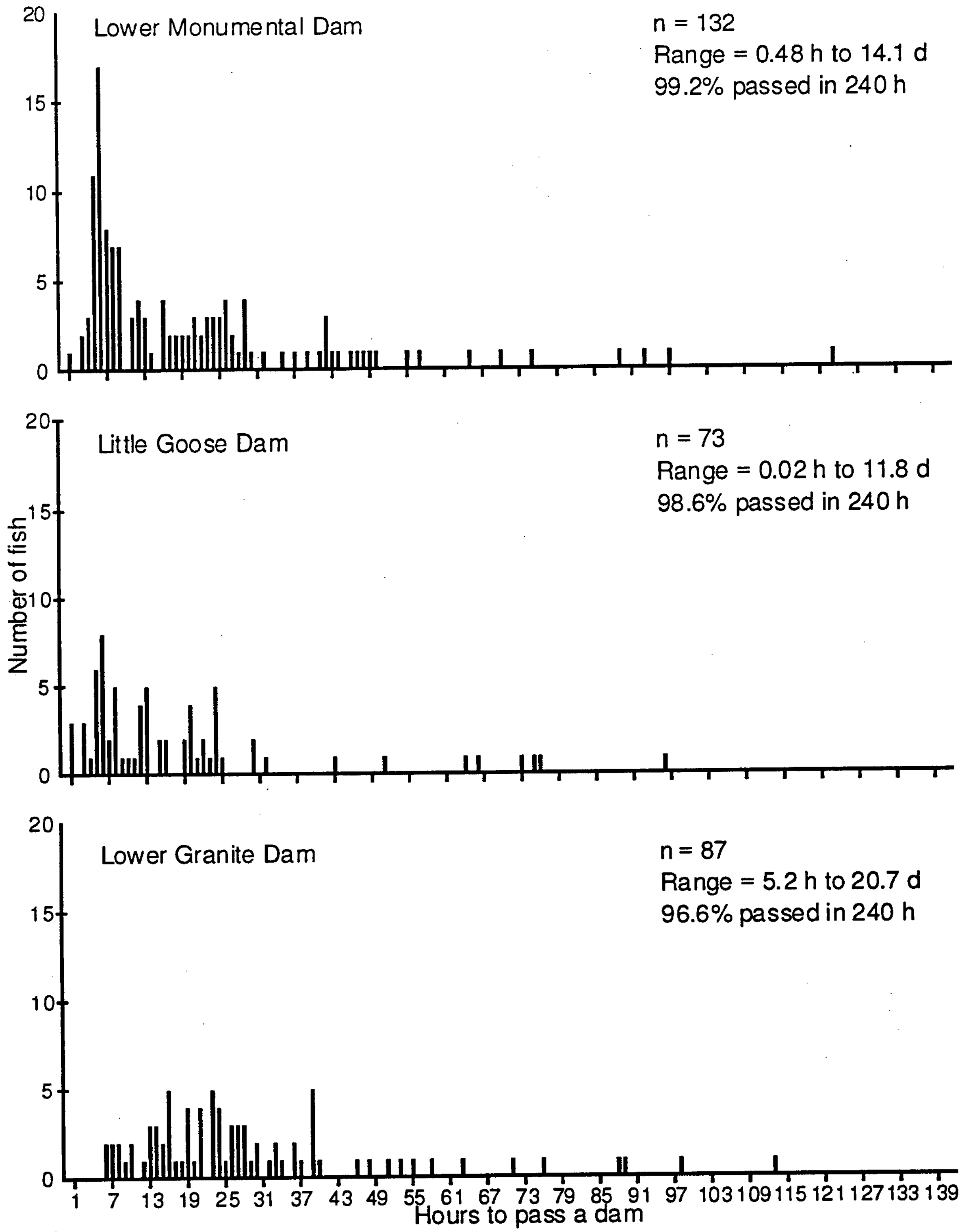



Figure 18. Frequency distribution of the time for steelhead to pass dams in the lower Snake River in 1991. Steelhead released at Charbonneau Campground in the fall that crossed over Lower Granite Dam before 31 December 1991.

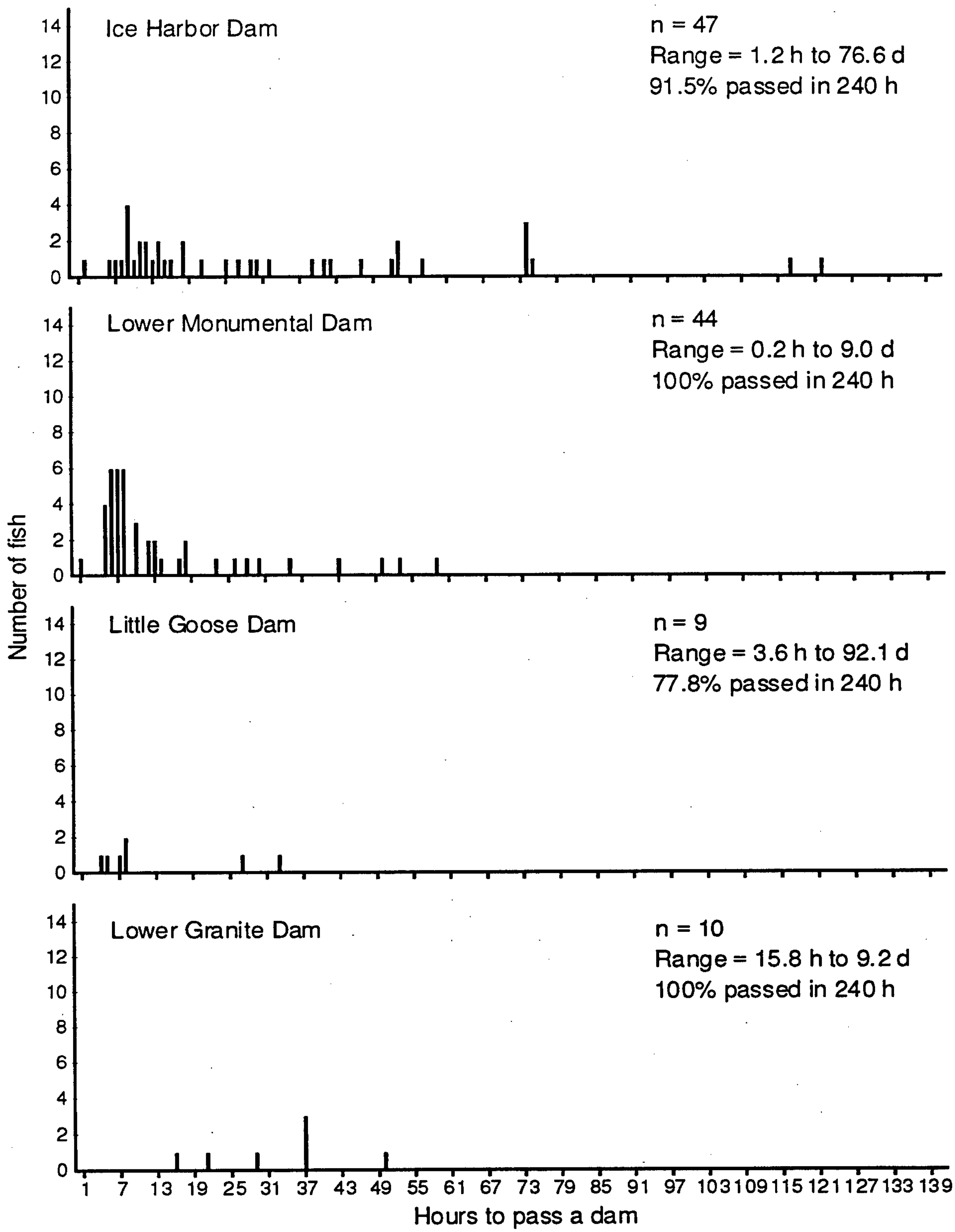



Figure 19. Frequency distribution of the time for steelhead to pass dams in the lower Snake River in 1991. Steelhead released at Hood Park in July that crossed over Lower Granite Dam before 31 December 1991.

Table 8. Migration rates of steelhead released in 1991 with transmitters as they migrated through reservoirs and in free flowing sections of rivers as measured by fish recorded at receivers at the dams and at fixed location sites in the rivers for fish passing Lower Granite Dam before 31 December 1991.

| Section of River | Number of fish | Mean travel rates Days | Mean travel rates Km/day | Median travel rates Days | Median travel rates Km/day |
|---|---|---|---|---|---|
| Through reservoirs | | | | | |
| Ice Harbor to Lower Monumental Dams | | | | | |
| HPK July released fish | 40 | 9.1 | 5.5 | 1.2 | 40.1 |
| HPK fall released fish | 78 | 10.2 | 4.9 | 3.2 | 15.6 |
| CHAR fall released fish | 162 | 5.1 | 9.4 | 2.2 | 22.2 |
| Lower Monumental to Little Goose Dams | | | | | |
| HPK July released fish | 30 | 3.1 | 14.7 | 1.6 | 28.2 |
| HPK fall released fish | 57 | 1.8 | 25.1 | 1.3 | 34.7 |
| CHAR fall released fish | 94 | 2.8 | 16.6 | 2.0 | 23.1 |
| Little Goose to Lower Granite Dams | | | | | |
| HPK July released fish | 6 | 22.8 | 2.6 | 2.0 | 29.8 |
| HPK fall released fish | 30 | 2.5 | 23.3 | 2.2 | 26.7 |
| CHAR fall released fish | 56 | 3.1 | 19.1 | 2.1 | 28.1 |
| Lower Granite to Clearwater River Site | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 24 | 50.7 | 1.2 | 33.9 | 1.7 |
| CHAR fall released fish | 38 | 48.2 | 1.2 | 37.3 | 1.6 |
| Lower Granite Dam to Snake River Site | | | | | |
| HPK July released fish | 7 | 6.3 | 10.2 | 4.3 | 15.0 |
| HPK fall released fish | 45 | 4.6 | 14.0 | 3.4 | 19.0 |
| CHAR fall released fish | 49 | 5.6 | 11.5 | 3.0 | 21.4 |
| Release to Clearwater River Site | | | | | |
| HPK July released fish | 1 | 210.4 | 1.1 | | |
| HPK fall released fish | 30 | 75.1 | 3.0 | 55.8 | 4.1 |
| CHAR fall released fish | 43 | 63.4 | 3.4 | 55.3 | 3.9 |

Table 8. continued.

| Section of River | Number of fish | Mean travel rates Days | Mean travel rates Km/day | Median travel rates Days | Median travel rates Km/day |
|---|---|---|---|---|---|
| Release to Snake River Site | | | | | |
| HPK July released fish | 15 | 94.2 | 2.5 | 76.6 | 3.0 |
| HPK fall released fish | 55 | 36.4 | 6.4 | 33.4 | 7.0 |
| CHAR fall released fish | 63 | 23.7 | 9.2 | 16.1 | 13.6 |
| Through Rivers | | | | | |
| Snake River to Grande Ronde River Sites | | | | | |
| HPK July released fish | 1 | 1.3 | 27.0 | | |
| HPK fall released fish | 1 | 31.4 | 1.1 | | |
| CHAR fall released fish | 5 | 66.8 | 0.5 | 25.6 | 1.4 |
| Snake River to Lower Salmon River Sites | | | | | |
| HPK July released fish | 5 | 14.6 | 14.0 | 10.8 | 19.0 |
| HPK fall released fish | 18 | 42.9 | 4.8 | 17.6 | 11.7 |
| CHAR fall released fish | 14 | 50.9 | 4.0 | 23.8 | 8.6 |
| Lower Salmon to South Fork Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 3 | 118.8 | 1.1 | 160.8 | 0.8 |
| CHAR fall released fish | 1 | 27.4 | 4.8 | | |
| Lower Salmon to Middle Fork Salmon Sites | | | | | |
| HPK July released fish | 4 | 17.3 | 10.5 | 16.3 | 11.1 |
| HPK fall released fish | 8 | 106.4 | 1.7 | 124.0 | 1.5 |
| CHAR fall released fish | 9 | 107.6 | 1.7 | 125.8 | 1.4 |
| Lower Salmon to Upper Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 0 | | | | |
| CHAR fall released fish | 2 | 162.6 | 1.5 | 162.6 | 1.5 |

Table 9. Migration rates of steelhead with transmitters released in the fall of 1991 as they migrated through reservoirs and in free flowing sections of rivers in 1991-1992 as measured by fish recorded at receivers at the dams and at fixed location sites in the rivers for fish passing Lower Granite Dam after 31 December 1991.

| Section of River | Number of fish | Mean travel rates | | Median travel rates | |
|---|---|---|---|---|---|
| | | Days | Km/day | Days | Km/day |
| Through reservoirs | | | | | |
| Ice Harbor to Lower Monumental Dams | | | | | |
| HPK July released fish | 1 | 1.6 | 31.2 | | |
| HPK fall released fish | 11 | 30.6 | 1.6 | 2.5 | 20.3 |
| Lower Monumental to Little Goose Dams | | | | | |
| HPK July released fish | 1 | 87.8 | 0.5 | | |
| HPK fall released fish | 13 | 22.5 | 2.0 | 1.4 | 33.2 |
| CHAR fall released fish | 6 | 21.5 | 2.1 | 3.8 | 12.1 |
| Little Goose to Lower Granite Dams | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 6 | 6.3 | 9.3 | 1.8 | 33.1 |
| CHAR fall released fish | 9 | 36.7 | 1.6 | 4.8 | 12.2 |
| Lower Granite Dam to Clearwater River Site | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 7 | 1.2 | 48.7 | 1.2 | 48.7 |
| CHAR fall released fish | 4 | 2.4 | 24.2 | 1.8 | 32.1 |
| Lower Granite Dam to Snake River Site | | | | | |
| HPK July released fish | 1 | 1.6 | 40.7 | | |
| HPK fall released fish | 2 | 1.5 | 42.7 | 1.5 | 42.7 |
| CHAR fall released fish | 0 | | | | |
| Release to Clearwater River Site | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 10 | 185.3 | 1.2 | 184.6 | 1.2 |
| CHAR fall released fish | 8 | 153.8 | 1.4 | 150.7 | 1.4 |
| Release to Snake River Site | | | | | |
| HPK July released fish | 1 | 259.6 | 0.9 | | |
| HPK fall released fish | 3 | 173.8 | 1.3 | 187.2 | 1.2 |
| CHAR fall released fish | 0 | | | | |

Table 9. continued.

| Section of River | Number of fish | Mean travel rates Days | Mean travel rates Km/day | Median travel rates Days | Median travel rates Km/day |
|---|---|---|---|---|---|
| **Through Rivers** | | | | | |
| Snake River to Grande Ronde River Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 1 | 0.6 | 65.7 | | |
| CHAR fall released fish | 0 | | | | |
| Snake River to Lower Salmon River Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 1 | 5.1 | 40.2 | | |
| CHAR fall released fish | 0 | | | | |
| Lower Salmon to South Fork Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 1 | 9.4 | 14.0 | | |
| CHAR fall released fish | 0 | | | | |
| Lower Salmon to Middle Fork Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 0 | | | | |
| CHAR fall released fish | 0 | | | | |
| Lower Salmon to Upper Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 0 | | | | |
| CHAR fall released fish | 0 | | | | |

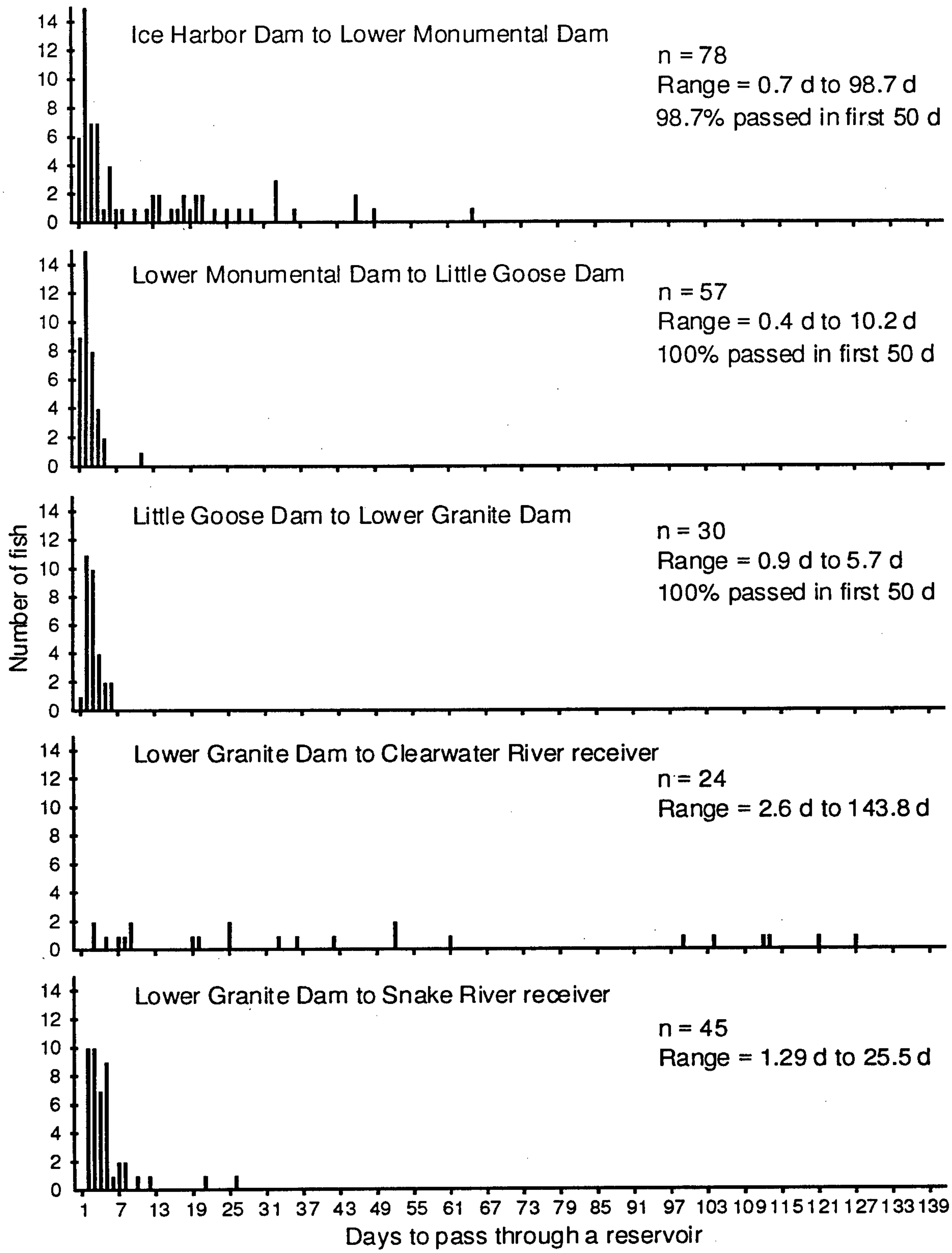



Figure 20. Frequency distribution of the time steelhead with transmitters took to pass through lower Snake River reservoirs in 1991. Steelhead released at Hood Park in the fall that crossed over Lower Granite Dam before 31 December 1991.

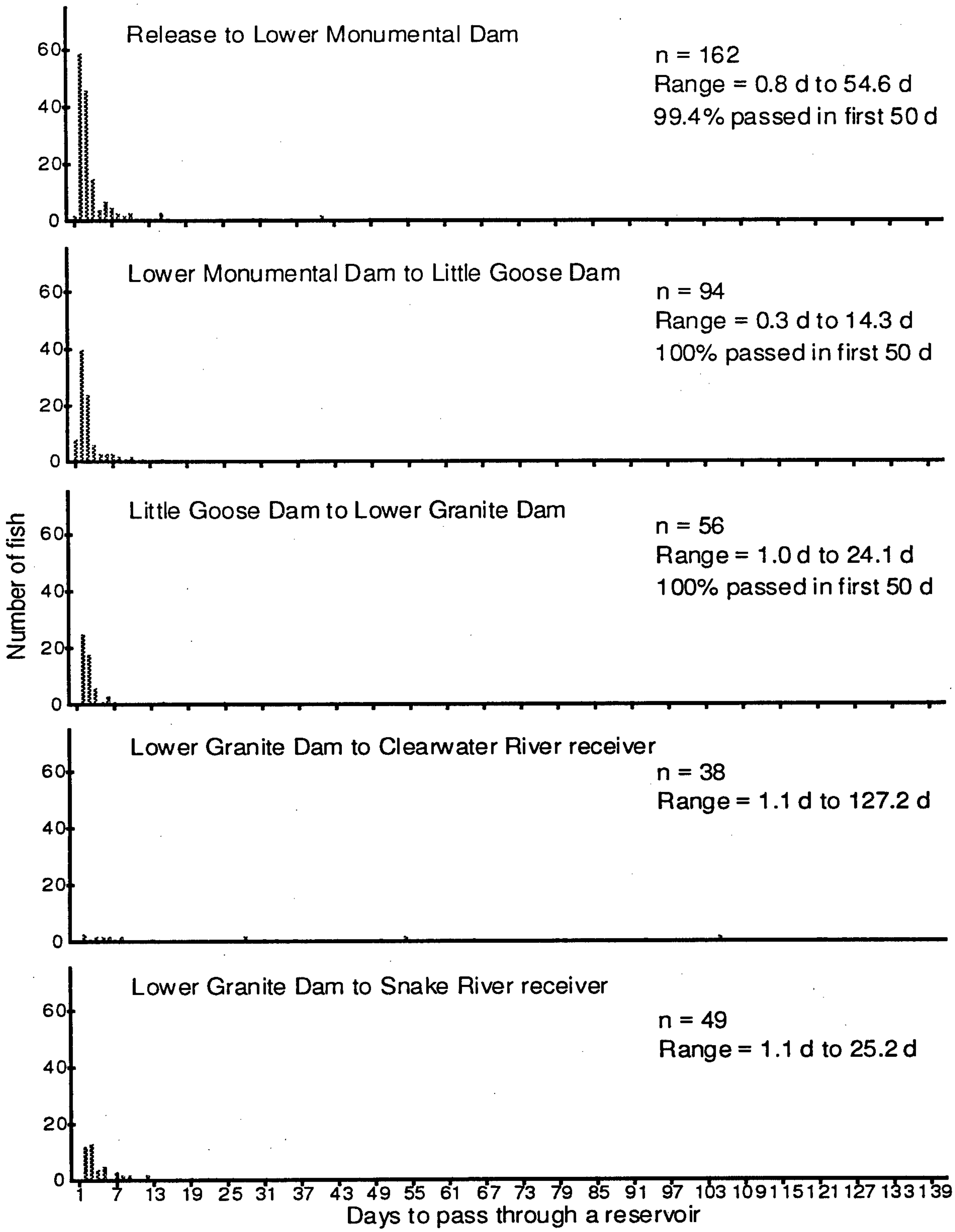



Figure 21. Frequency distribution of the time steelhead with transmitters took to pass through lower Snake River reservoirs in 1991. Steelhead released at Charbonneau Campground in the fall that crossed over Lower Granite Dam before 31 December 1991.

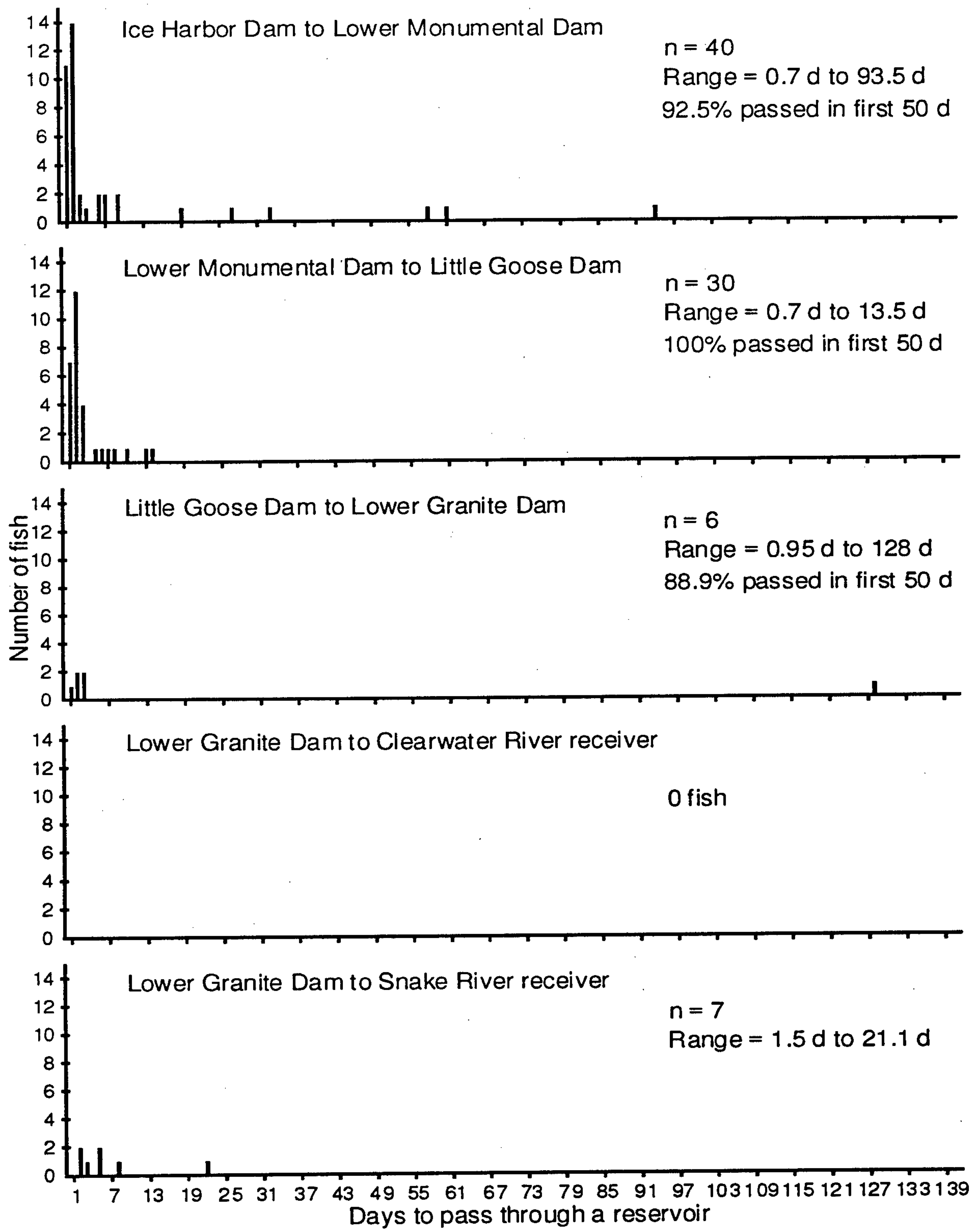



Figure 22. Frequency distribution of the time steelhead with transmitters took to pass through lower Snake River reservoirs in 1991. Steelhead released at Hood Park in July that crossed over Lower Granite Dam before 31 December 1991.

***Recaptures of steelhead tagged in 1991.-*** Of the 2,710 steelhead outfitted with transmitters or tagged with spaghetti-loop tags in 1991, reports were returned to us for 922 of the fish that had been taken in fisheries (736), recaptured at hatcheries (147) or found dead in the rivers (39)(Table 10). In addition, 2,223 of the tagged fish (82%) were recaptured in the Lower Granite trap from July 1991 through May 1992.

Of the 736 steelhead reported caught in fisheries, 36 were fish that had moved downstream into the Columbia River after release and 26 were caught there, and 10 others were caught after having moved up into the Walla Walla River (Figure 23). A total of 47 steelhead (5.1% of those recaptured, excluding recaptures at the Lower Granite trap) were recorded as having moved downstream into the Columbia River after tagging and release, with one fish trapped at Priest Rapids Dam, 10 fish found dead. and 36 caught in fisheries (Table 10).

The largest number of recaptures for a reach of river, was from the lower Snake River (mouth to Lewiston) where 223 steelhead were caught from the Snake River, 11 from the Tucannon River, 10 were taken in traps, and 7 were found dead (27.2% of the recaptured fish, Table 10).

There were 103 steelhead reported taken by anglers from the Snake River between Lewiston and the Salmon River, 8 fish taken upstream from the Salmon River, and 9 trapped at Hells Canyon Dam, 12.9% of the recaptures (Table 10).

In the Clearwater River basin, 103 steelhead were reported caught from the main stem Clearwater River and 36 from the North Fork (Figure 23). Sixty-three of the tagged steelhead entered Dworshak NFH, 1 in Kooskia NFH, 2 at a trap in the upper tributaries, and 4 were found dead, for a total of 209 fish (22.7% of the recaptures, Table 10).

Sixty-seven steelhead (7.3% of recaptures) were reported as recaptures in the Grande Ronde River basin with 54 taken in the fishery and 13 into hatcheries (Table 10). Seventeen steelhead were reported from the Imnaha River basin, with 3 taken in the fishery and 14 trapped at the weir.

Anglers fishing the Salmon River reported catching 159 tagged steelhead, 1 was found dead, 24 were taken at Pahsimeroi SFH, and 26 at Sawtooth SFH for a total of 210 recaptures (22.8% of recaptures, Table 10).

Table 10. Recaptures of the 734 steelhead with transmitters and the 1,976 fish tagged with spaghetti-loop tags and released at Hood Park or Charbonneau campgrounds near Ice Harbor Dam in 1991. Recaptures occurred from July 1991 through May 1992.

| Recapture location | Type of recapture | Number of fish |
|---|---|---|
| Columbia River | | |
| Upstream from Snake River | Fishery | 9 |
| Priest Rapids Dam | Trap | 1 |
| | Found dead | 2 |
| Downstream from Snake River | Fishery | 17 |
| | Found Dead | 8 |
| Walla Walla River | Fishery | 10 |
| Snake River | | |
| Mouth to Lewiston | Fishery | 223 |
| | Found dead | 7 |
| Lyons Ferry Hatchery | Trap | 9 |
| Tucannon River | Fishery | 11 |
| | Hatchery | 1 |
| Lower Granite Adult Trap | Trap | 2,223 |
| Lewiston to Salmon River | Fishery | 103 |
| Salmon River to Hells Canyon Dam | Fishery | 8 |
| Hells Canyon Dam | Trap | 9 |
| Clearwater River | Fishery | 103 |
| North Fork | Fishery | 36 |
| Dworshak Fish Hatchery | Trap | 63 |
| Kooskia Fish Hatchery | Trap | 1 |
| Upper Clearwater and tributaries | Trap | 2 |
| | Found dead | 4 |
| Grande Ronde River | Fishery | 54 |
| | Hatchery | 13 |
| Salmon River | Fishery | 159 |
| | Found dead | 1 |
| Pahsimeroi Fish Hatchery | Trap | 24 |
| Sawtooth Fish Hatchery | Trap | 26 |
| Imnaha River | Fishery | 3 |
| | Trap | 14 |
| | Total | 3,145 |
| | Hatcheries | 147 |
| | Fisheries | 736 |

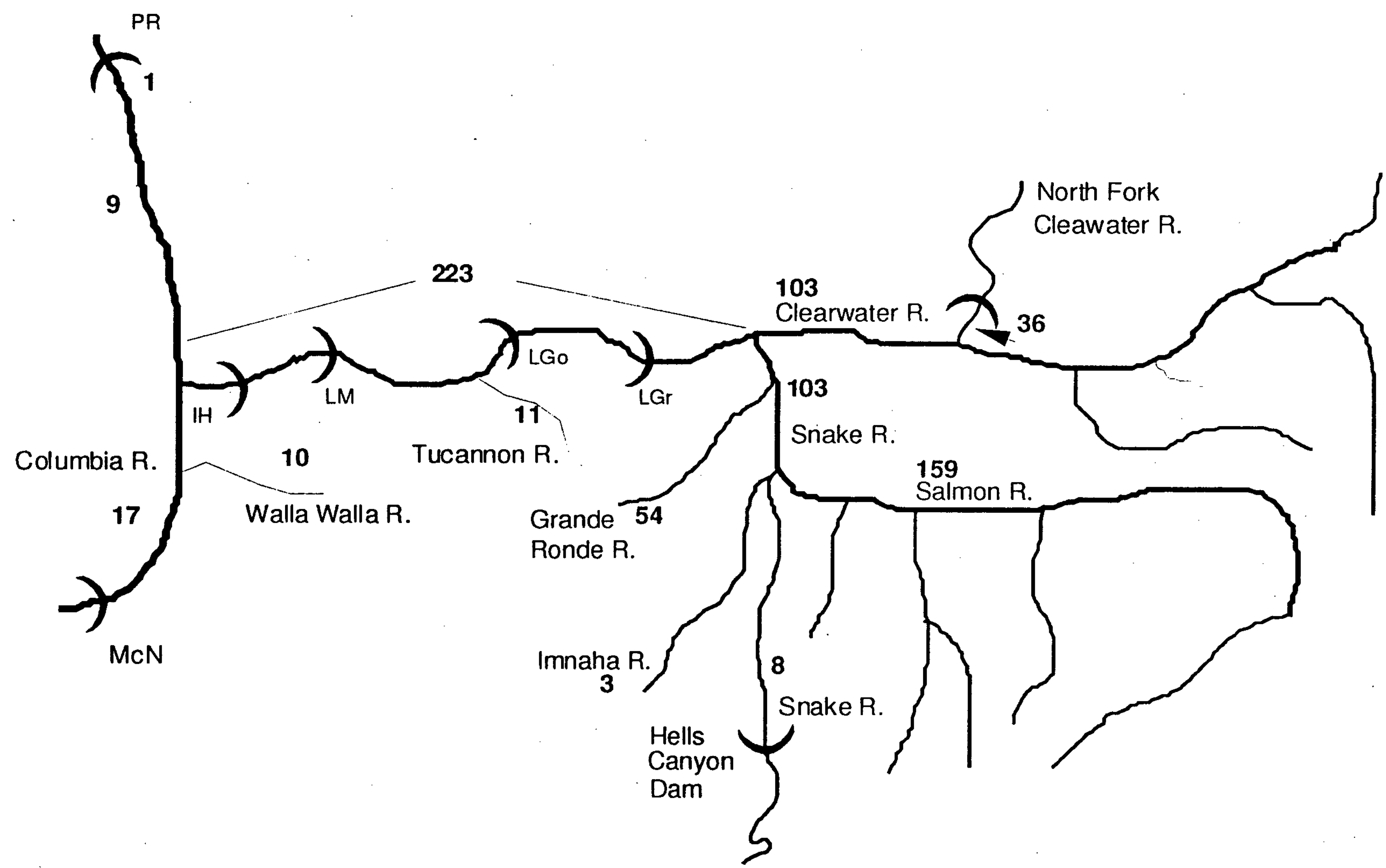



Figure 23. Reported recaptures by anglers of steelhead with transmitters and spaghetti-loop tags released near Ice Harbor Dam in 1991, and recaptured through the spring of 1992.

In 1991, 208 (28%) of the 734 steelhead released with transmitters were wild fish and the remainder were classified as hatchery fish on the basis of fin clips. Of 201 steelhead with transmitters reported by anglers as being caught, 32 (16%) were wild fish of which 11 were kept, 17 were released, and the disposition of 4 fish was unknown. Of the 169 hatchery steelhead with transmitters reported caught by anglers, 158 were kept, 6 were reported released, and the disposition of 5 fish was unknown.

Steelhead released with spaghetti-loop tags for the zero-flow test in 1991 were also caught by anglers, but they were all hatchery fish. Of the 524 fish reported caught, 477 were kept, 16 were released, and the disposition of 28 fish was unknown.

***Distribution of steelhead outfitted with transmitters in 1991.-*** Steelhead outfitted with transmitters in 1991 were tracked as they migrated past the dams and into the tributaries of the Snake River through the end of the spawning period in May of 1992. The distribution of those fish based on last sitings at fixed-site receivers, by mobile tracking, and by recaptures by anglers, at weirs and hatcheries is presented in Table 11. Fifty of the 734 (6.8%) fish released with transmitters were not located again; 48 of the 50 were fish released at Hood Park, with many of those released in July of 1991.

Eighty-five (11.6%) of the released fish were last located back downstream in the Columbia River or a tributary; the Walla Walla River (Table 11). Fifty-four of the fish were found in the Columbia River upstream from the Snake River, and 28 were found downstream, with 4 in the Walla Walla River.

Within the Snake River, 18 of the steelhead were last recorded downstream from Ice Harbor Dam, and another 68 were last recorded at the dam or in the reservoir upstream from the dam (Table 11). Lower Monumental Dam and Reservoir were the sites of last recordings for 44 steelhead, Little Goose Dam and Reservoir for 34 fish, and Lower Granite Dam and Reservoir for 52 fish. An additional 66 fish were last recorded at the adult trap at Lower Granite Dam. Ten fish entered Lyons Ferry Hatchery and 1 fish was located in the Tucannon River. A total of 293 steelhead (40% of those released) were last located in the lower Snake River, downstream from the receiver sites on the lower Clearwater River and Snake River upstream from Lewiston. Several of the fish were harvested by anglers.

Table 11. Distribution of steelhead released with transmitters in 1991 based on last sitings at receivers or by mobile tracking, and recaptures by anglers, at weirs, or at hatcheries.

| Location of last siting | Number of fish | Percent of recaptures |
|---|---|---|
| Release sites near Ice Harbor Dam | | |
| Hood Park | 48 | 6.5 |
| Charbonneau Campground | 2 | 0.3 |
| Columbia River | 3 | 0.4 |
| Upstream from Snake River | 54 | 7.4 |
| Downstream from Snake River | 24 | 3.3 |
| Walla Walla River | 4 | 0.5 |
| Lower Snake River | | |
| Downstream from Ice Harbor Dam | 18 | 2.5 |
| Ice Harbor Dam and Reservoir | 68 | 9.3 |
| Lower Monumental Dam and Reservoir | 44 | 6.0 |
| Lyons Ferry Hatchery | 10 | 1.4 |
| Tucannon River | 1 | 0.1 |
| Little Goose Dam and Reservoir | 34 | 4.6 |
| Lower Granite Dam and Reservoir | 52 | 7.1 |
| Lower Granite adult trap | 66 | 9.0 |
| Clearwater River drainage | | |
| Receiver site near mouth | 28 | 3.8 |
| Clearwater River, mouth to North Fork | 57 | 7.8 |
| Clearwater River, North Fork to Lowell | 3 | 0.4 |
| Dworshak National Fish Hatchery | 26 | 3.5 |
| Kooskia National Fish Hatchery | 1 | 0.1 |
| North Fork of Clearwater River | 15 | 2.0 |
| Lochsa River | 4 | 0.5 |
| Selway River | 1 | 0.1 |
| South Fork of Clearwater River | 1 | 0.1 |
| Snake River upstream from Lewiston | | |
| Lewiston to Salmon River | 49 | 6.7 |
| Snake River receiver site near Asotin | 21 | 2.9 |
| Salmon River to Hells Canyon Dam | 2 | 0.3 |
| Hells Canyon Dam | 4 | 0.5 |
| Grande Ronde River drainage | | |
| Receiver site near mouth | 3 | 0.4 |
| Grande Ronde River | 7 | 1.0 |
| Wallowa River | 2 | 0.3 |
| Imnaha River drainage | | |
| Imnaha River | 1 | 0.1 |
| Imnaha River weir | 2 | 0.3 |

Table 11. Continued.

| Location of last siting | Number of fish | Percent of recaptures |
|---|---|---|
| Salmon River drainage | | |
| Salmon River, mouth to Riggins | 15 | 2.0 |
| Receiver site at Riggins | 7 | 1.0 |
| Little Salmon River | 2 | 0.3 |
| Rapid River trap | 1 | 0.1 |
| Salmon River, Riggins to South Fork | 6 | 0.8 |
| South Fork of Salmon River | 12 | 1.6 |
| Salmon River, South Fork to Middle Fork | 0 | 0.0 |
| Receiver at mouth of Middle Fork | 16 | 2.2 |
| Salmon River, Middle Fork to North Fork | 5 | 0.7 |
| Receiver at North Fork | 4 | 0.5 |
| Salmon River upstream from North Fork | 9 | 1.2 |
| Pahsimeroi River | 1 | 0.1 |
| East Fork of Salmon River | 1 | 0.1 |
| Totals | 734 | 100.0 |

Of the 306 steelhead last located upstream from Lower Granite Reservoir, 136 (44%) entered the Clearwater River, and 170 proceeded up the Snake River upstream from Lewiston (Table 11). Of those last recorded in the Clearwater drainage, 27 entered the hatcheries, and the remainder of the last sitings were scattered along the main stem (88 fish) and in the main tributaries (21 fish).

Of the 170 steelhead that migrated up the Snake River, 76 were last sited in the Snake River from Lewiston upstream to Hells Canyon Dam, 12 entered the Grande Ronde drainage, 3 entered the Imnaha River, and 79 entered the Salmon River (Table 11). Within the Salmon River drainage, 37 of the steelhead were last recorded in the main stem from the mouth upstream to North Fork, 3 entered the Little Salmon River, 12 entered the South Fork, 16 likely entered the Middle Fork, and 11 were found in streams upstream from North Fork.

### *Methods - Steelhead Tagged in 1992*

Migration rates and passage at the dams and into the tributaries of the Snake River were assessed for steelhead in 1992 in a similar manner as was described for chinook salmon. The receivers set up to monitor chinook salmon movements at the dams and mouths of the major tributaries were also used to monitor steelhead movements. Newly

developed Digital Spectrum Processors were set up at the Lower Granite Dam fishway in July of 1992 with underwater antennas to monitor fishway entrance use, movements in the fishway, and fallout of fish from the fishway.

Capture and outfitting of steelhead with transmitters at Ice Harbor Dam in 1992 began at the end of June and continued through mid July, then resumed again on 1 September when the river cooled some and fish began migrating over Ice Harbor Dam in large enough numbers to provide the sample sizes needed (Figure 24). Trapping and tagging continued through 8 November 1992.

Four groups of steelhead were released with transmitters and jaw tags in 1992, 59 fish released at Hood Park in July, 89 fish at Charbonneau Campground in July, 258 fish at Hood Park in the fall, and 288 fish at Charbonneau Campground in the fall, for a total of 694.

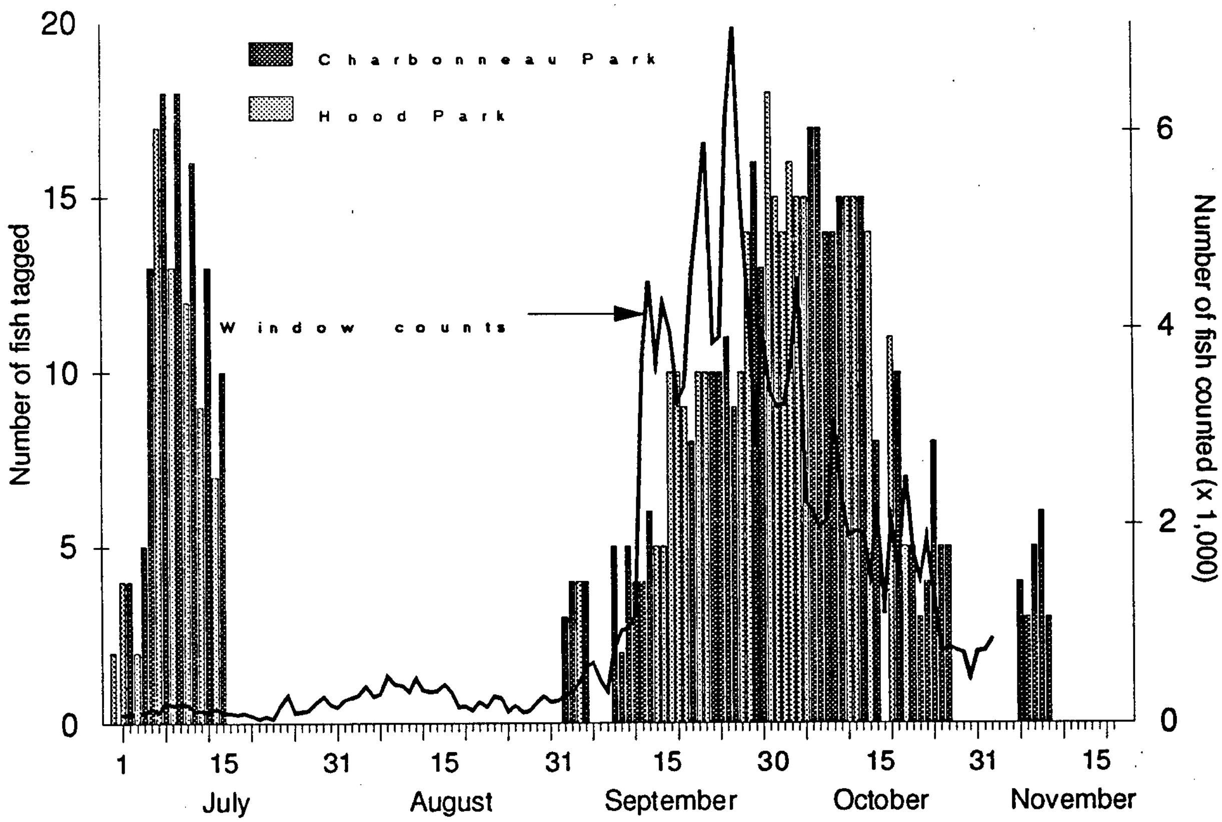



Figure 24. The number of steelhead counted at Ice Harbor Dam during the summer and fall of 1992, and the number outfitted with transmitters and released at Hood Park or Charbonneau campgrounds near the dam.

Water temperatures in the river and the fishways at the dams exceeded 20 $^{o}C$ during the latter part of July, August, and early September in 1992. Temperatures at the tops of the ladders ranged from 23 to 25 $^{o}C$ during August, and few fish entered the Snake River until early September.

Steelhead outfitted with transmitters in 1992 were monitored with the new digital spectrum processors (DSP) and receivers at Lower Granite Dam to evaluate the telemetry system and to assess fish movements into and through the fishway. Coxial cable antennas were placed at each entrance to the fishway, in the collection channel across from each entrance, and at the bottom and top of the ladder (Figure 25). Up to four antennas were connected to a receiver. Unlike the standard SRX-400 receiver which scanned each frequency for six seconds, the DSPs scanned all of the frequencies instantaneously and if a fish was present within range of one of the antennas, the pulse-code signal was passed on to the receiver and recorded. Thus, it was less likely that a fish with a transmitter could swim past an antenna without being recorded after we began using the new DSP units.

### *Results - Steelhead Tagged in 1992*

***Passage success.***- Of the 59 steelhead released at Hood Park with transmitters in July of 1992, 30 were recorded as entering the tailrace at Ice Harbor Dam, 21 at Lower Monumental Dam, 21 at Little Goose Dam, and 18 at Lower Granite Dam (Figure 26). Twenty-two of the 59 steelhead released in July were recaptured at the Lower Granite trap, none were recorded going into the Clearwater River (only 1 did so in 1991), and 14 were recorded migrating up the Snake River near Asotin. Fifty-one percent of the fish released in July at Hood Park were recorded as having returned back upstream to the Ice Harbor tailrace, 54% were recorded exiting the top of the ladder, and 37% were recaptured in the trap at Lower Granite Dam.

Eighty-nine steelhead were released at Charbonneau Campground with transmitters in July of 1992, and 49 moved downstream, fell back over Ice Harbor Dam and were recorded in the tailrace, 41 moved upstream to the tailrace at Lower Monumental Dam, 21 at Little Goose Dam, and 21 at Lower Granite Dam (Figure 26). Thirty-two of the 89 steelhead released in July were recaptured at the Lower Granite trap, only three were recorded going into the Clearwater River, and 12 were recorded migrating up the Snake

River near Asotin. Fifty-five percent of the fish released in July at Charbonneau Campground were recorded as having returned back downstream to the Ice Harbor tailrace, 35% of those that fell back over Ice Harbor Dam were recorded re-ascending and exiting the top of the ladder, and 36% of the fish released were recaptured in the trap at Lower Granite Dam. Fallback of adult steelhead at Lower Granite Dam in 1992 occurred at a low rate; 930 fish collected at the juvenile separator in July through November amounted to about 1% of the more than 90,000 steelhead passing the dam in 1992.

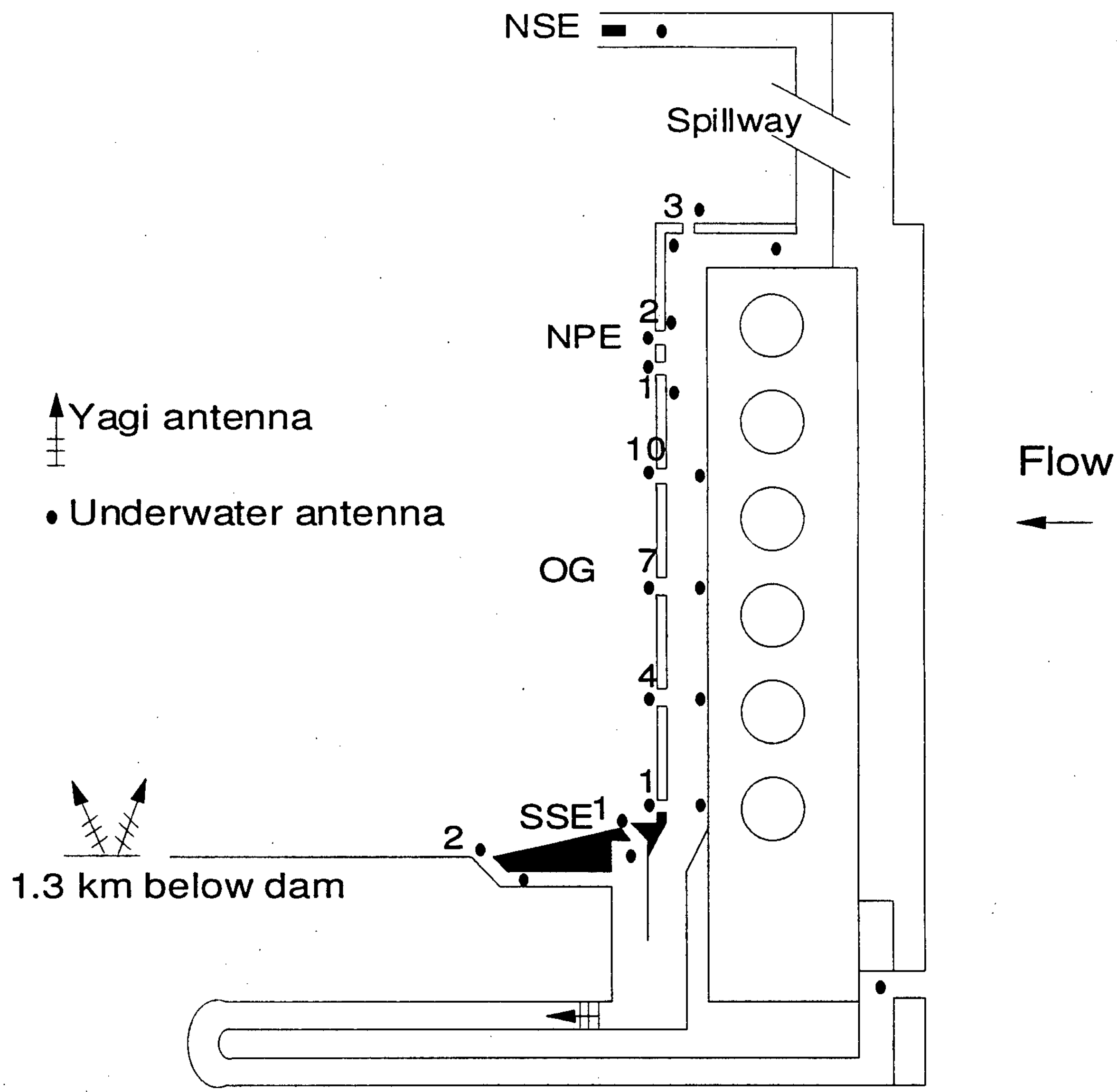



Figure 25. Diagram of Lower Granite Dam with locations of antennas to monitor movements of steelhead as they approached the dam, entered and moved through the fishway and left the top of the ladder in the summer and fall 1992.

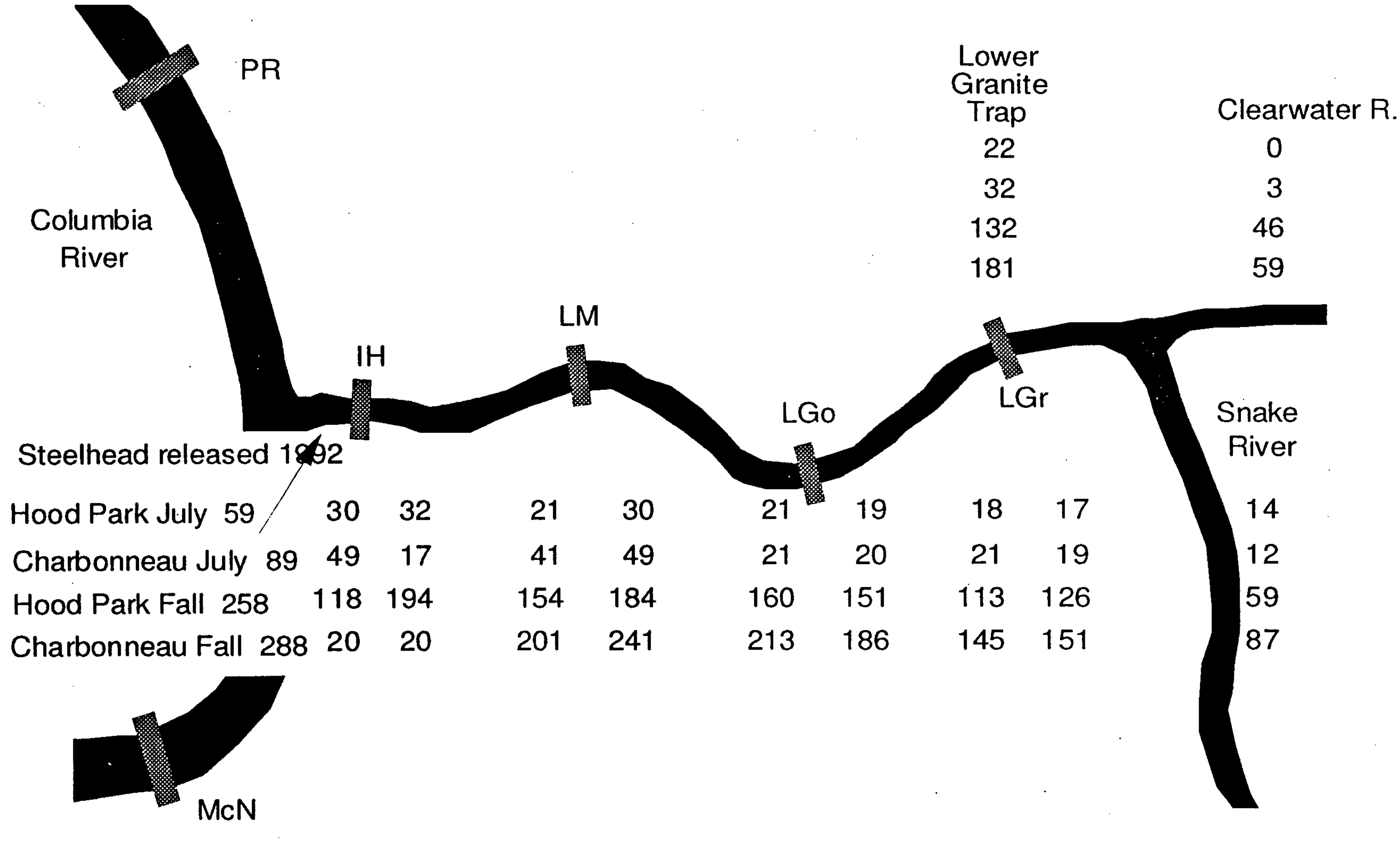



Figure 26. Numbers of steelhead released with transmitters in 1992 at Hood Park and Charbonneau Campground in July and in the fall, the numbers of each group recorded at receivers in the tailraces and top of ladders at each of the dams and at the lower Clearwater River and Snake River near Asotin receiver sites through May of 1993.

Of the 258 steelhead released at Hood Park with transmitters in the fall of 1992, 118 were recorded as entering the tailrace at Ice Harbor Dam, 154 at Lower Monumental Dam, 160 at Little Goose Dam, and 113 at Lower Granite Dam (Figure 26). At the Lower Granite adult trap, 132 of the 258 steelhead released in the fall at Hood Park were recaptured, and 46 were recorded going into the Clearwater River and 59 were recorded migrating up the Snake River near Asotin. Fourty-six percent of the 258 fish released at Hood Park in the fall were recorded back up in the Ice Harbor tailrace, 75% were recorded exiting the ladder, and 51% were recaptured in the trap at Lower Granite Dam.

The group of steelhead released at Charbonneau Campground upstream from Ice Harbor Dam in the fall of 1992 had higher percentages passing the remainder of the dams in the Lower Snake River than the groups of fish released at Hood Park downstream from the dam. Of the 288 steelhead released at Charbonneau Campground, 20 were recorded back downstream in the Ice Harbor Dam tailrace (20 of the group also migrated upstream through the ladder at Ice Harbor Dam), 201 were recorded as entering the tailrace at Lower Monumental Dam, 213 at Little Goose Dam, and 145 at Lower Granite Dam (Figure 26). Sixty-three percent (181) of the fish released at Charbonneau were recaptured at the Lower Granite adult trap, 52% were recorded exiting the ladder of the upper dam, 59 fish were recorded going into the Clearwater River, and 87 fish were recorded migrating up the Snake River near Asotin.

Similar percentages of steelhead released near Ice Harbor Dam in 1992 were recorded as passing the upstream dams as those observed for steelhead in 1991, but still lower than for chinook salmon (about 87% of the salmon passed Lower Granite Dam in 1991 and 80% in 1992). For steelhead with transmitters in 1992, the percentages of fish released that were recaptured at the Lower Granite trap were 37% (18% in 1991) for those released at Hood Park in July, 51% (55% in 1991) for those released at Hood Park in the fall, and 63% (73% in 1991) for those released upstream from Ice Harbor Dam in the fall. As in 1991, removal of fish by the fishery downstream from Lower Granite Dam is a partial explanation for the reduced proportion passing upstream; about 8% of the steelhead with transmitters were reported caught by anglers from the lower Snake River. A high percentage (55%) of the steelhead released at Charbonneau Campground in July returned back downstream and fell back over Ice Harbor Dam versus only 7% of the fish released at the campground in the fall. The proportions of steelhead released at Charbonneau Campground with spaghetti-loop tags in the fall for the zero-flow test that passed over Lower Granite Dam were similar to the proportions for steelhead with transmitters in 1992.

***Migration rates.*** - Steelhead released at Hood Park in July and in the fall of 1992 took an average of 40.5 and 11.2 d, respectively, to return back upstream to the tailrace of Ice Harbor Dam (median days were 46.1 and 5.1 respectively, Table 12), rates that were similar to those recorded in 1991 (Table 6). Steelhead released at Charbonneau Campground in July and the fall took an average of 26.6 and 5.6 d (median days of 3.1 and 3.0), respectively, to migrate upstream to the tailrace of Lower Monumental Dam. Chinook salmon in 1992, for comparison, took 2.2 d to migrate back upstream from Hood Park to the tailrace of Ice Harbor Dam. The few fish that were released in 1992, but did not migrate over Lower Granite Dam until spring of 1993, took 36.4 to 212.6 d on average (median days of 1.0 to 212) to migrate to the tailraces of Ice Harbor or Lower Monumental dams (Table 13).

The mean time for steelhead released in the fall to migrate from the tailrace to the top of the ladder at the four lower Snake River dams in the fall of 1992, ranged from 6.8 d at Ice Harbor Dam to 1.0 d at Little Goose Dam (median days 2.6 to 0.4, Table 12). Passage times for steelhead released in July of 1992 were more variable (0.7 to 18.4 mean d, and 0.2 to 1.7 median d) than those of fish released in the fall, as was the case in 1991 (Table 6). The above listed rates were for fish that crossed over Lower Granite Dam before 31 December 1991, and represent fish that were intent on migrating through the lower Snake River in the fall. For fish that did not pass Lower Granite Dam until after 31 December (mostly in March and April of 1993), the time to pass a dam was more variable (up to a mean of 52.6 d and median days of 2.7) than for the fall migrating fish (Table 13).

As with chinook salmon in 1991 and 1992, and steelhead in 1991, passage time for steelhead that migrated through the lower Snake River in the fall of 1992 was highest at Ice Harbor Dam (mean d of 6.8, median of 2.6 d), relatively short at Lower Monumental and Little Goose dams (mean days of 1.0-2.2, median days of 0.4-0.9), and higher at Lower Granite Dam (Table 12). Time for a fish to pass a dam was measured as the lapsed time from the last record of a fish at the tailrace receivers to the last record from the same fish on a receiver at the top of the ladders.

The distributions of passage time at the four lower Snake River dams for steelhead released at Hood Park in the fall of 1992 and migrating past Lower Granite Dam in the fall, were spread out for fish passing Ice Harbor and Lower Granite dams versus a definite modal distribution for steelhead passing the other two dams (Figure 27). High percentages of the fish passed each of the dams within 2 d. About 26% of the fish passing Ice Harbor Dam took more than 10 d, but less than 3% of the steelhead passing the other dams took more than 10 d.

Table 12. Mean and median number of days (and range) for steelhead released with transmitters in 1992 to migrate from the Hood Park release site to the tailrace of Ice Harbor Dam and from the Charbonneau Park release site to the tailrace of Lower Monumental Dam, and to pass each of the four dams in the Lower Snake River for fish passing Lower Granite Dam before 31 December 1992.

| | Number of fish | Mean number of days | Range of days | Median number of days |
|---|---|---|---|---|
| Hood Park (HPK) to Ice Harbor Dam | | | | |
| July released fish | 27 | 40.5 | 0.6-131.0 | 46.1 |
| Fall released fish | 114 | 11.2 | 0.3-58.1 | 5.1 |
| Charbonneau Park (CHAR) to Lower Monumental Dam | | | | |
| July released fish | 39 | 26.6 | 1.3-109.8 | 3.1 |
| Fall released fish | 183 | 5.6 | 0.8-47.1 | 3.0 |
| Past a Dam | | | | |
| Ice Harbor | | | | |
| HPK July released fish | 19 | 18.4 | N/A-140.3 | 1.7 |
| HPK fall released fish | 103 | 6.8 | 0.2-68.6 | 2.6 |
| Lower Monumental | | | | |
| HPK July released fish | 17 | 4.9 | 0.2-66.4 | 1.7 |
| HPK fall released fish | 134 | 1.4 | 0.3-48.6 | 0.6 |
| CHAR July released fish | 37 | 4.4 | 0.2-46.7 | 0.8 |
| CHAR fall released fish | 155 | 2.2 | 0.2-30.6 | 0.9 |
| Little Goose | | | | |
| HPK July released fish | 16 | 1.1 | 0.1-4.9 | 0.7 |
| HPK fall released fish | 140 | 1.0 | 0.2-4.9 | 0.4 |
| CHAR July released fish | 16 | 0.7 | 0.05-6.7 | 0.2 |
| CHAR fall released fish | 168 | 1.5 | 0.1-19.5 | 0.6 |
| Lower Granite | | | | |
| HPK July released fish | 16 | 16.0 | 0.2-227.4 | 1.3 |
| HPK fall released fish | 97 | 1.7 | 0.2-17.4 | 1.0 |
| CHAR July released fish | 15 | 5.4 | 0.1-42.3 | 1.1 |
| CHAR fall released fish | 101 | 3.5 | 0.2-163.4 | 1.3 |

Table 13. Mean and median number of days (and range) for steelhead released with transmitters in 1992 to migrate from the Hood Park release site to the tailrace of Ice Harbor Dam and from the Charbonneau Park release site to the tailrace of Lower Monumental Dam, and to pass each of the four dams in the lower Snake River for fish passing Lower Granite Dam after 31 December 1992.

| | Number of fish | Mean number of days | Range of days | Median number of days |
|---|---|---|---|---|
| Hood Park (HPK) to Ice Harbor Dam | | | | |
| July released fish | 3 | 36.4 | 0.9-107.4 | 1.0 |
| Fall released fish | 12 | 97.6 | 3.0-194.7 | 103.0 |
| Charbonneau Park (CHAR) to Lower Monumental Dam | | | | |
| July released fish | 2 | 212.6 | 141.1-284.1 | 212.6 |
| Fall released fish | 17 | 37.1 | 1.7-178.9 | 5.1 |
| Past a Dam | | | | |
| Ice Harbor | | | | |
| HPK July released fish | 3 | 42.5 | 0.9-121.7 | 4.9 |
| HPK fall released fish | 9 | 20.0 | 0.4-163.8 | 2.3 |
| Lower Monumental | | | | |
| HPK July released fish | 2 | 4.2 | 0.4-7.9 | 4.2 |
| HPK fall released fish | 12 | 1.5 | 0.3-5.1 | 0.8 |
| CHAR July released fish | 1 | 1.2 | | 1.2 |
| CHAR fall released fish | 16 | 9.5 | 0.3-100.6 | 1.4 |
| Little Goose | | | | |
| HPK July released fish | 1 | 19.9 | | 19.9 |
| HPK fall released fish | 6 | 5.6 | 0.2-25.9 | 1.0 |
| CHAR July released fish | 1 | 0.2 | | 0.2 |
| CHAR fall released fish | 12 | 23.7 | 0.2-133.8 | 1.3 |
| Lower Granite | | | | |
| HPK July released fish | 1 | 34.1 | | 34.1 |
| HPK fall released fish | 6 | 1.4 | 0.5-2.4 | 1.4 |
| CHAR July released fish | 1 | 6.6 | | 6.6 |
| CHAR fall released fish | 9 | 52.6 | 0.4-151.1 | 2.7 |

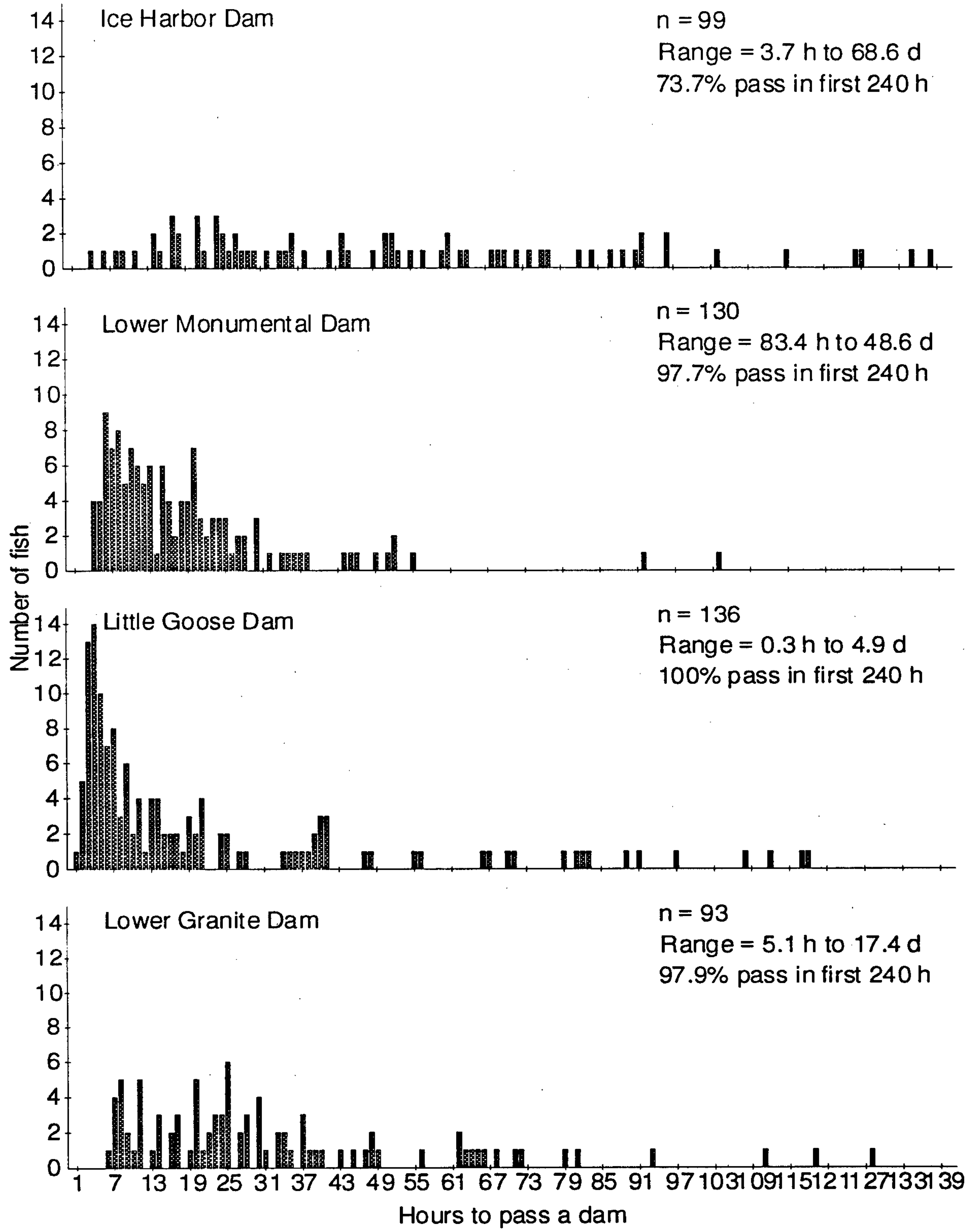



Figure 27. Frequency distribution for steelhead passing from the tailrace to the top of the ladder at each of the dams in the lower Snake River in 1992. Steelhead released at Hood Park in the fall and migrating over Lower Granite Dam before 31 December 1992.

The distributions of passage times at three Snake River dams for steelhead released at Charbonneau and Hood Park campgrounds in the fall of 1992 and migrating past Lower Granite Dam in the fall (Figures 27 and 28) were similar in that most fish crossed the dams within 48 h, but the distributions were more spread out at Lower Granite and Ice Harbor dams. Five to seven percent of the fish released at Charbonneau Campground took more than 10 d to cross the dams.

Steelhead released in July of 1992 at both Hood Park and Charbonneau Campground had nearly uniform distributions of time to pass the dams, except for those passing Little Goose Dam where most fish passed over the dam in the first day (Figures 29 and 30).

The rates of migration of steelhead through the Snake River reservoirs in 1992 were generally about half that for chinook salmon, and similar to the rates of steelhead in 1991. Steelhead released in the fall of 1992 that migrated over Lower Granite Dam before 31 December 1992 had migration rates based on mean days to pass that ranged from 13 to 27 km/d (20 to 34 km/d in 1991) (Table 14). As with steelhead in 1991, steelhead that migrated from Lower Granite Dam forebay into the Clearwater River in 1992 had a slower migration rate (mean of 1.3 km/d) than fish that migrated into the Snake River near Asotin (4.7-7.8 km/d), or through the other reservoirs. Steelhead that did not cross Lower Granite Dam until after 31 December had more variable migration rates (Table 15).

Migration rates of steelhead in the free-flowing sections of the Snake, Clearwater, and Salmon rivers were slower than those in the reservoirs (Tables 14 and 15). In the free-flowing rivers, steelhead migrated at mean rates of <1 to 14 km/d depending on section of the rivers, versus rates in the reservoirs of 13-27 km/d. The slower migration rates in the rivers is mostly due to the fact that steelhead cease migrating in the fall and spend the winter in the rivers. Many of the fish migrated to the upper end of Lower Granite Reservoir or into the Snake, Clearwater, and lower Salmon rivers where they ceased migrating in November or December and did not resume upstream movements until the next spring.

Most steelhead migrated through the individual lower Snake River reservoirs in less than 10 d, especially those steelhead that migrated past Lower Granite Dam before 31 December 1992. Many of the steelhead released in the fall at Hood Park and Charbonneau campgrounds moved through the first three pools in about 4 d, but the migration rates through the Lower Granite pool to the Clearwater or Snake River receiver sites were slower, and about half the fish took more than 10 d to reach those upper river sites (Figures 31 and 32). Distributions for steelhead released in July tended to be uniform for the first 8 to 10 d of migration through each reservoir (Figures 33 and 34).

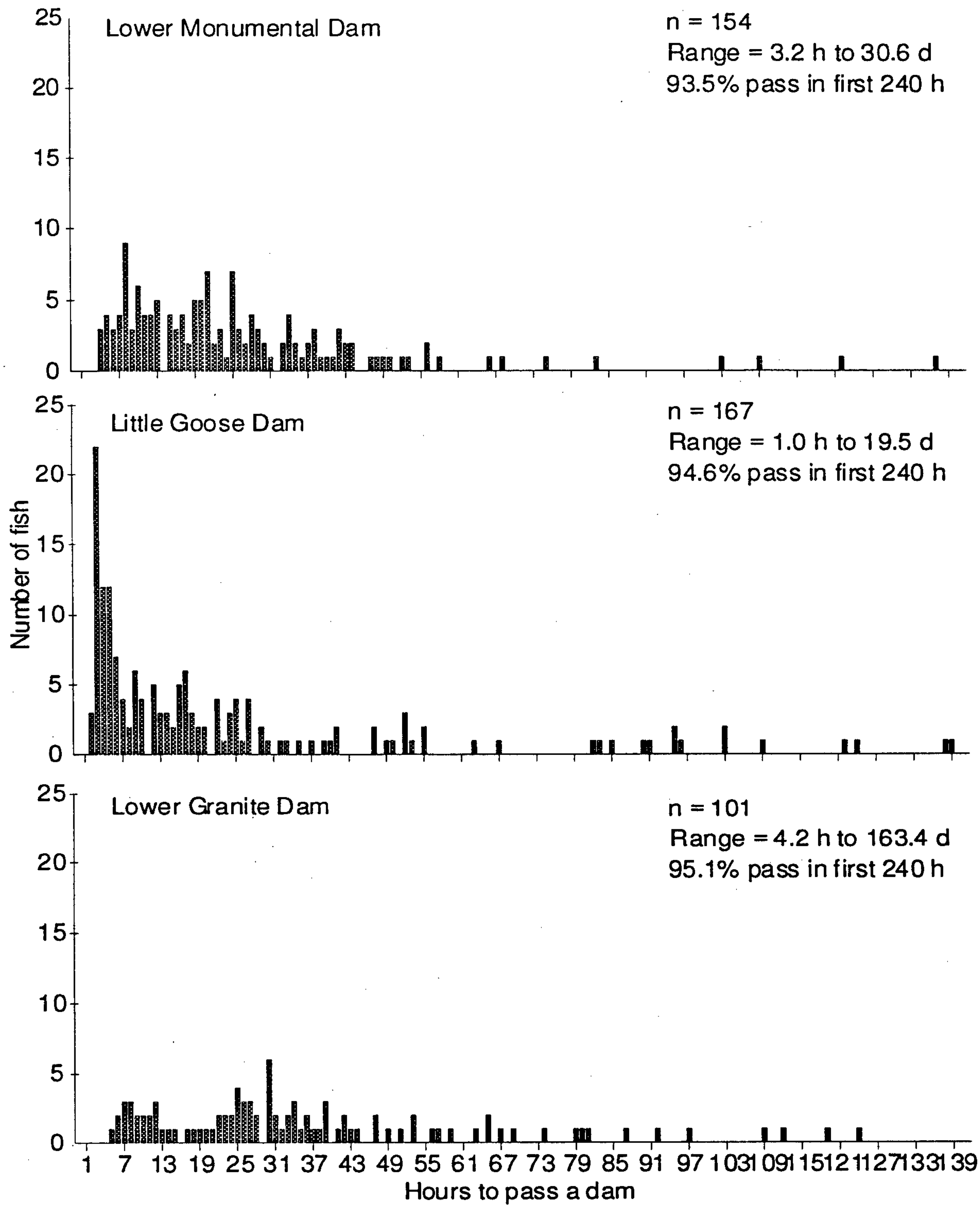



Figure 28. Frequency distribution for steelhead passing from the tailrace to the top of the ladder at each of the dams in the lower Snake River in 1992. Steelhead released at Charbonneau Campground in the fall and migrating over Lower Granite Dam before 31 December 1992.

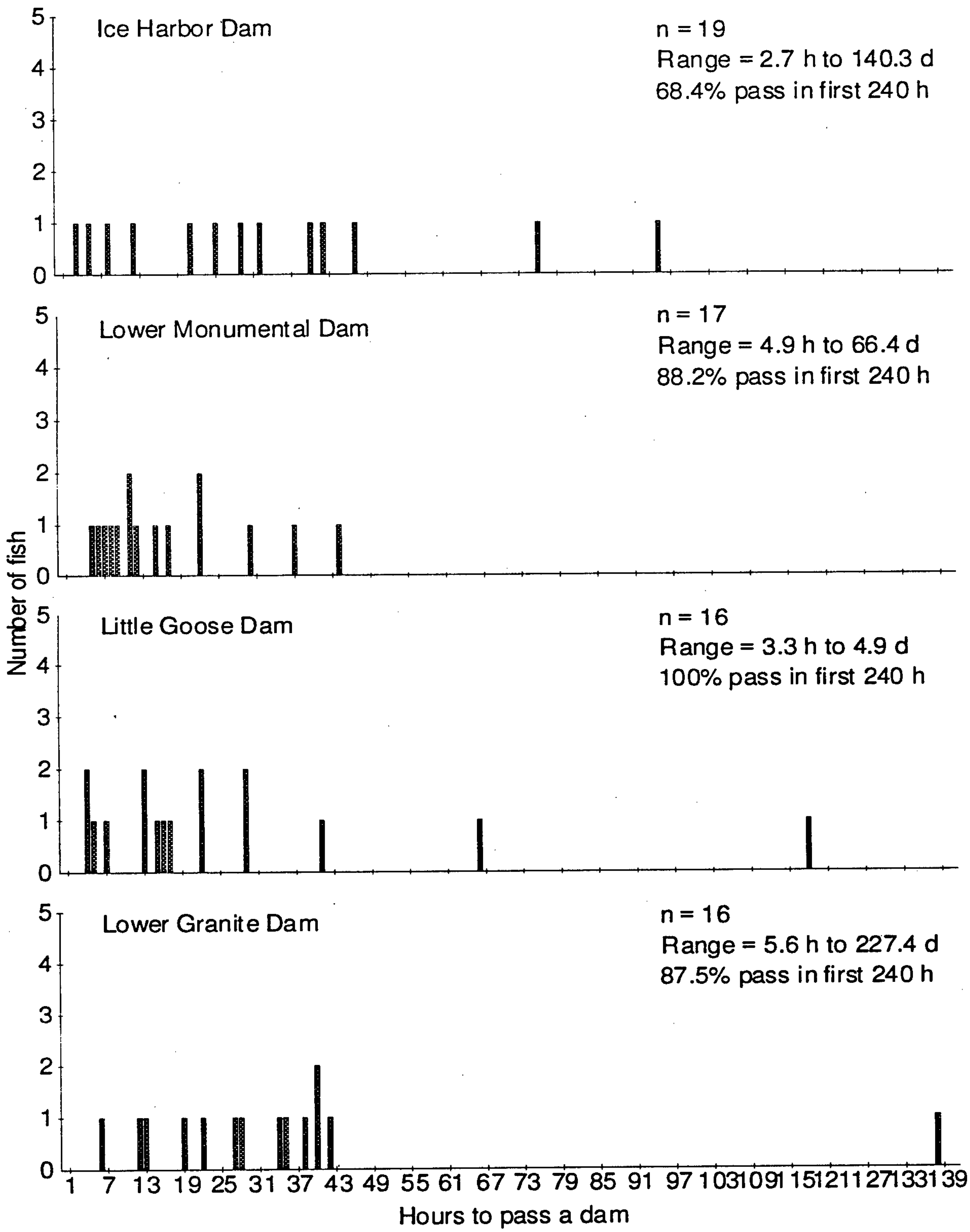



Figure 29. Frequency distribution for steelhead passing from the tailrace to the top of the ladder at each of the dams in the lower Snake River in 1992. Steelhead released at Hood Park in July and migrating over Lower Granite Dam before 31 December 1992.

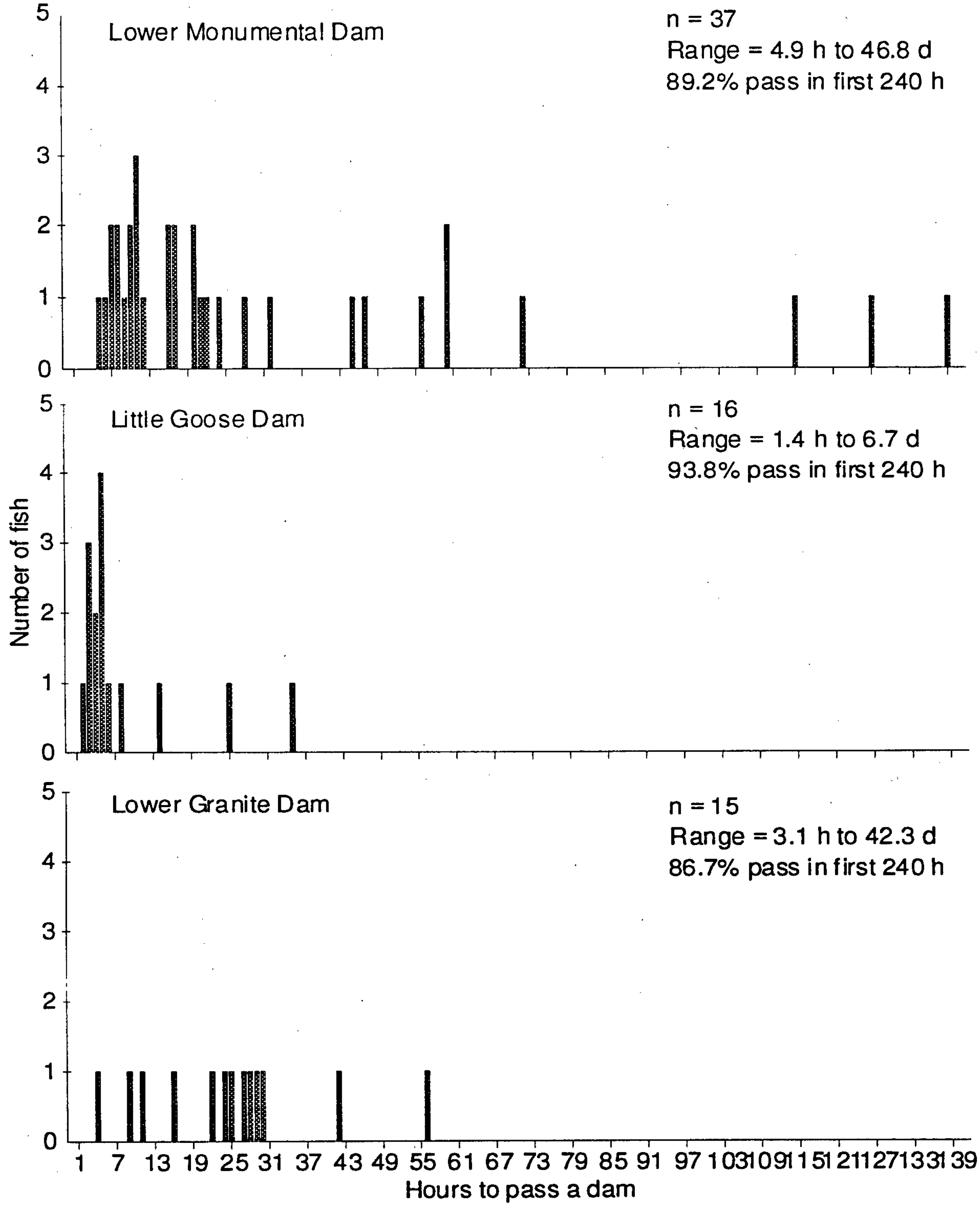



Figure 30. Frequency distribution for steelhead passing from the tailrace to the top of the ladder at each of the dams in the lower Snake River in 1992. Steelhead released at Charbonneau Campground in July and migrating over Lower Granite Dam before 31 December 1992.

Table 14. Migration rates of steelhead released with transmitters in 1992 as they migrated through reservoirs and in free flowing sections of river as measured by fish recorded at receivers at the dams and at fixed location sites in the rivers for fish passing Lower Granite Dam before 31 December 1992.

| Section of River | Number of fish | Mean travel rates Days | Mean travel rates Km/day | Median travel rates Days | Median travel rates Km/day |
|---|---|---|---|---|---|
| Through reservoirs | | | | | |
| Ice Harbor to Lower Monumental Dams | | | | | |
| HPK July released fish | 16 | 3.1 | 16.3 | 2.5 | 20.0 |
| HPK fall released fish | 131 | 2.7 | 18.7 | 1.7 | 30.4 |
| Lower Monumental to Little Goose Dams | | | | | |
| HPK July released fish | 18 | 7.2 | 6.3 | 3.3 | 13.8 |
| HPK fall released fish | 142 | 3.0 | 15.4 | 2.4 | 19.1 |
| CHAR July released fish | 19 | 17.1 | 2.7 | 2.8 | 16.2 |
| CHAR fall released fish | 174 | 3.1 | 14.6 | 2.9 | 16.0 |
| Little Goose to Lower Granite Dams | | | | | |
| HPK July released fish | 17 | 1.8 | 32.8 | 1.8 | 32.8 |
| HPK fall released fish | 100 | 2.2 | 26.9 | 1.6 | 36.1 |
| CHAR July released fish | 17 | 2.0 | 29.9 | 1.8 | 33.5 |
| CHAR fall released fish | 120 | 4.4 | 13.4 | 2.0 | 29.7 |
| Lower Granite Dam to Clearwater River Site | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 36 | 44.5 | 1.3 | 8.6 | 6.8 |
| CHAR July released fish | 3 | 44.9 | 1.3 | 30.0 | 2.0 |
| CHAR fall released fish | 38 | 41.8 | 1.4 | 6.5 | 9.0 |
| Lower Granite Dam to Snake River Site | | | | | |
| HPK July released fish | 14 | 3.6 | 17.3 | 3.3 | 19.4 |
| HPK fall released fish | 48 | 13.7 | 4.7 | 4.7 | 13.7 |
| CHAR July released fish | 11 | 6.7 | 9.6 | 3.1 | 20.7 |
| CHAR fall released fish | 70 | 8.2 | 7.8 | 4.1 | 15.5 |
| Release to Clearwater River Site | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 37 | 74.9 | 3.0 | 46.5 | 4.9 |
| CHAR July released fish | 3 | 142.6 | 1.5 | 166.7 | 1.3 |
| CHAR fall released fish | 46 | 59.7 | 3.6 | 27.1 | 7.9 |

Table 14. continued.

| Section of River | Number of fish | Mean travel rates Days | Mean travel rates Km/day | Median travel rates Days | Median travel rates Km/day |
|---|---|---|---|---|---|
| Release to Snake River Site | | | | | |
| HPK July released fish | 13 | 90.2 | 2.6 | 88.3 | 2.6 |
| HPK fall released fish | 57 | 36.1 | 6.5 | 28.1 | 8.3 |
| CHAR July released fish | 11 | 89.6 | 2.4 | 94.5 | 2.3 |
| CHAR fall released fish | 86 | 21.6 | 10.1 | 15.1 | 14.6 |
| Through Rivers | | | | | |
| Snake River to Grande Ronde River Sites | | | | | |
| HPK July released fish | 1 | 1.5 | 23.3 | 1.5 | 23.3 |
| HPK fall released fish | 10 | 42.9 | 0.8 | 7.4 | 4.9 |
| CHAR July released fish | 0 | | | | |
| CHAR fall released fish | 9 | 75.2 | 0.5 | 108.2 | 0.3 |
| Snake River to Lower Salmon River Sites | | | | | |
| HPK July released fish | 6 | 33.1 | 6.2 | 9.4 | 21.8 |
| HPK fall released fish | 19 | 75.3 | 2.7 | 33.8 | 6.1 |
| CHAR July released fish | 3 | 8.3 | 24.6 | 7.6 | 27.1 |
| CHAR fall released fish | 37 | 42.5 | 4.8 | 16.7 | 12.2 |
| Lower Salmon to South Fork Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 4 | 18.1 | 7.3 | 21.1 | 6.2 |
| CHAR July released fish | 0 | | | | |
| CHAR fall released fish | 1 | 183.1 | 0.7 | 183.1 | 0.7 |
| Lower Salmon to Middle Fork Salmon Sites | | | | | |
| HPK July released fish | 1 | 9.2 | 19.7 | 9.2 | 19.7 |
| HPK fall released fish | 6 | 13.3 | 13.6 | 11.0 | 16.5 |
| CHAR July released fish | 2 | 10.1 | 17.9 | 10.1 | 17.9 |
| CHAR fall released fish | 5 | 115.0 | 1.6 | 177.9 | 1.0 |
| Lower Salmon to Upper Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 2 | 12.6 | 19.2 | 12.6 | 19.2 |
| CHAR July released fish | 2 | 18.8 | 12.9 | 18.8 | 12.9 |
| CHAR fall released fish | 8 | 122.0 | 2.0 | 149.7 | 1.6 |

Table 15. Migration rates of steelhead released with transmitters in 1992 as they migrated through reservoirs and in free flowing sections of river as measured by fish recorded at receivers at the dams and at fixed location sites in the rivers for fish passing Lower Granite Dam after 31 December 1992.

| Section of River | Number of fish | Mean travel rates Days | Mean travel rates Km/day | Median travel rates Days | Median travel rates Km/day |
|---|---|---|---|---|---|
| Through reservoirs | | | | | |
| Ice Harbor to Lower Monumental Dams | | | | | |
| HPK July released fish | 4 | 73.2 | 0.7 | 4.9 | 10.1 |
| HPK fall released fish | 13 | 17.0 | 20.5 | 1.0 | 48.4 |
| Lower Monumental to Little Goose Dams | | | | | |
| HPK July released fish | 2 | 17.1 | 2.7 | 17.1 | 2.7 |
| HPK fall released fish | 8 | 2.4 | 19.4 | 2.1 | 21.5 |
| CHAR July released fish | 1 | 108.9 | 0.4 | 108.9 | 0.4 |
| CHAR fall released fish | 20 | 3.5 | 13.2 | 3.0 | 15.1 |
| Little Goose to Lower Granite Dams | | | | | |
| HPK July released fish | 1 | 54.7 | 1.1 | 54.7 | 1.1 |
| HPK fall released fish | 10 | 1.2 | 48.3 | 0.9 | 65.8 |
| CHAR July released fish | 1 | 3.2 | 18.4 | 3.2 | 18.4 |
| CHAR fall released fish | 15 | 6.9 | 8.5 | 2.2 | 26.3 |
| Lower Granite Dam to Clearwater River Site | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 8 | 1.4 | 41.8 | 1.2 | 47.5 |
| CHAR July released fish | 0 | | | | |
| CHAR fall released fish | 10 | 2.3 | 25.6 | 1.8 | 32.2 |
| Lower Granite Dam to Snake River Site | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 1 | 0.9 | 70.8 | 0.9 | 70.8 |
| CHAR July released fish | 1 | 2.1 | 31.4 | 2.1 | 31.4 |
| CHAR fall released fish | 2 | 1.4 | 44.5 | 1.4 | 44.5 |
| Release to Clearwater River Site | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 10 | 180.5 | 1.3 | 182.8 | 1.2 |
| CHAR July released fish | 0 | | | | |
| CHAR fall released fish | 12 | 149.5 | 1.4 | 154.9 | 1.4 |

Table 15. continued.

| Section of River | Number of fish | Mean travel rates Days | Mean travel rates Km/day | Median travel rates Days | Median travel rates Km/day |
|---|---|---|---|---|---|
| Release to Snake River Site | | | | | |
| HPK July released fish | 1 | 259.1 | 0.9 | 259.1 | 0.9 |
| HPK fall released fish | 1 | 174.7 | 1.3 | 174.7 | 1.3 |
| CHAR July released fish | 1 | 261.6 | 0.8 | 261.6 | 0.8 |
| CHAR fall released fish | 2 | 182.4 | 1.2 | 182.4 | 1.2 |
| Through Rivers | | | | | |
| Snake River to Grande Ronde River Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 0 | | | | |
| CHAR July released fish | 0 | | | | |
| CHAR fall released fish | 1 | 0.8 | 43.6 | 0.8 | 43.6 |
| Snake River to Lower Salmon River Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 1 | 4.0 | 51.4 | 4.0 | 51.4 |
| CHAR July released fish | 1 | 6.8 | 30.3 | 6.8 | 30.3 |
| CHAR fall released fish | 1 | 6.0 | 34.2 | 6.0 | 34.2 |
| Lower Salmon to South Fork Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 0 | | | | |
| CHAR July released fish | 0 | | | | |
| CHAR fall released fish | 0 | | | | |
| Lower Salmon to Middle Fork Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 0 | | | | |
| CHAR July released fish | 1 | 10.4 | 17.5 | 10.4 | 17.5 |
| CHAR fall released fish | 0 | | | | |
| Lower Salmon to Upper Salmon Sites | | | | | |
| HPK July released fish | 0 | | | | |
| HPK fall released fish | 0 | | | | |
| CHAR July released fish | 0 | | | | |
| CHAR fall released fish | 0 | | | | |

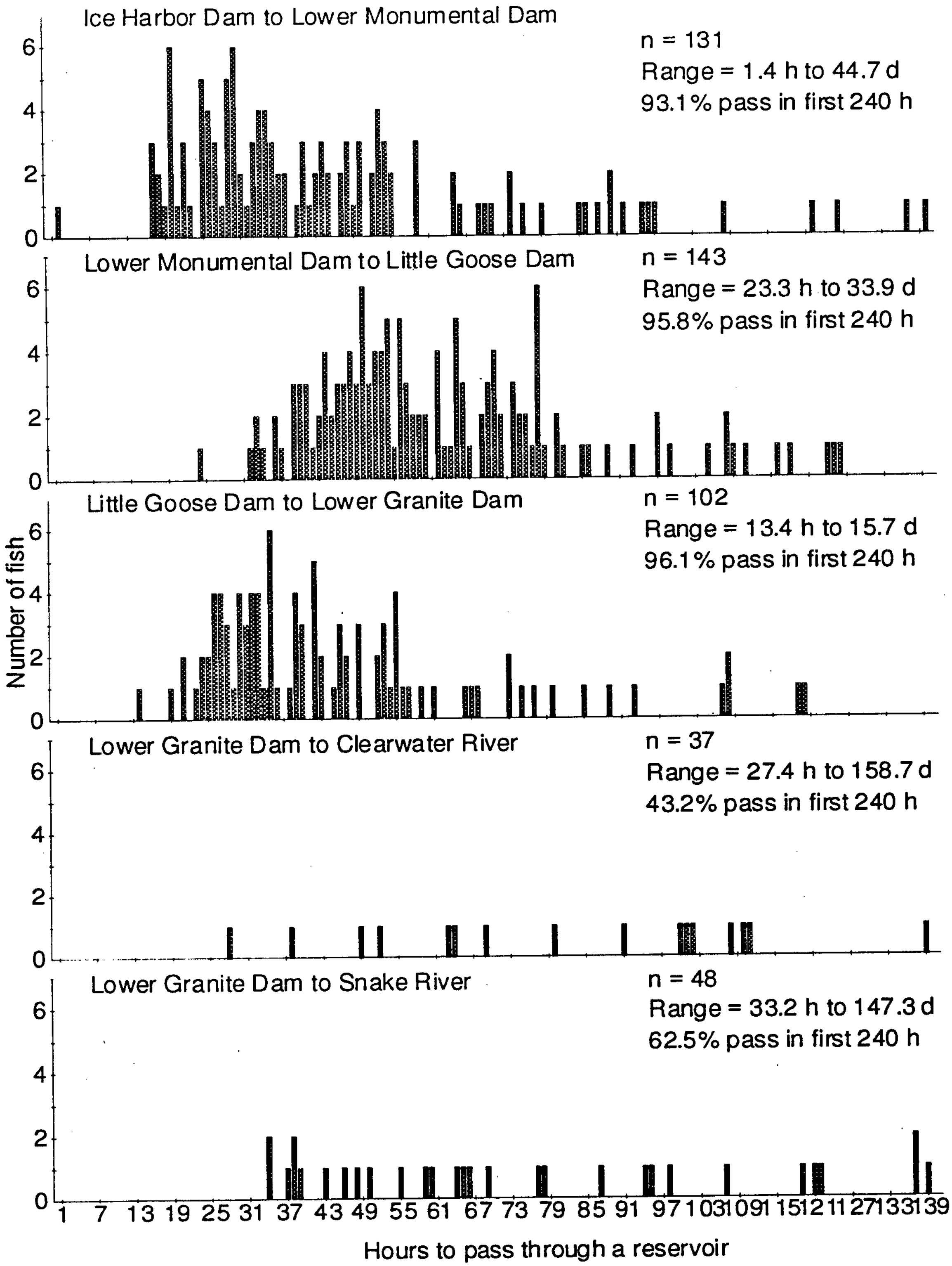



Figure 31. Frequency distribution for steelhead passing through each of the reservoirs in the lower Snake River in 1992. Steelhead released at Hood Park in the fall and migrating over Lower Granite Dam before 31 December 1992.

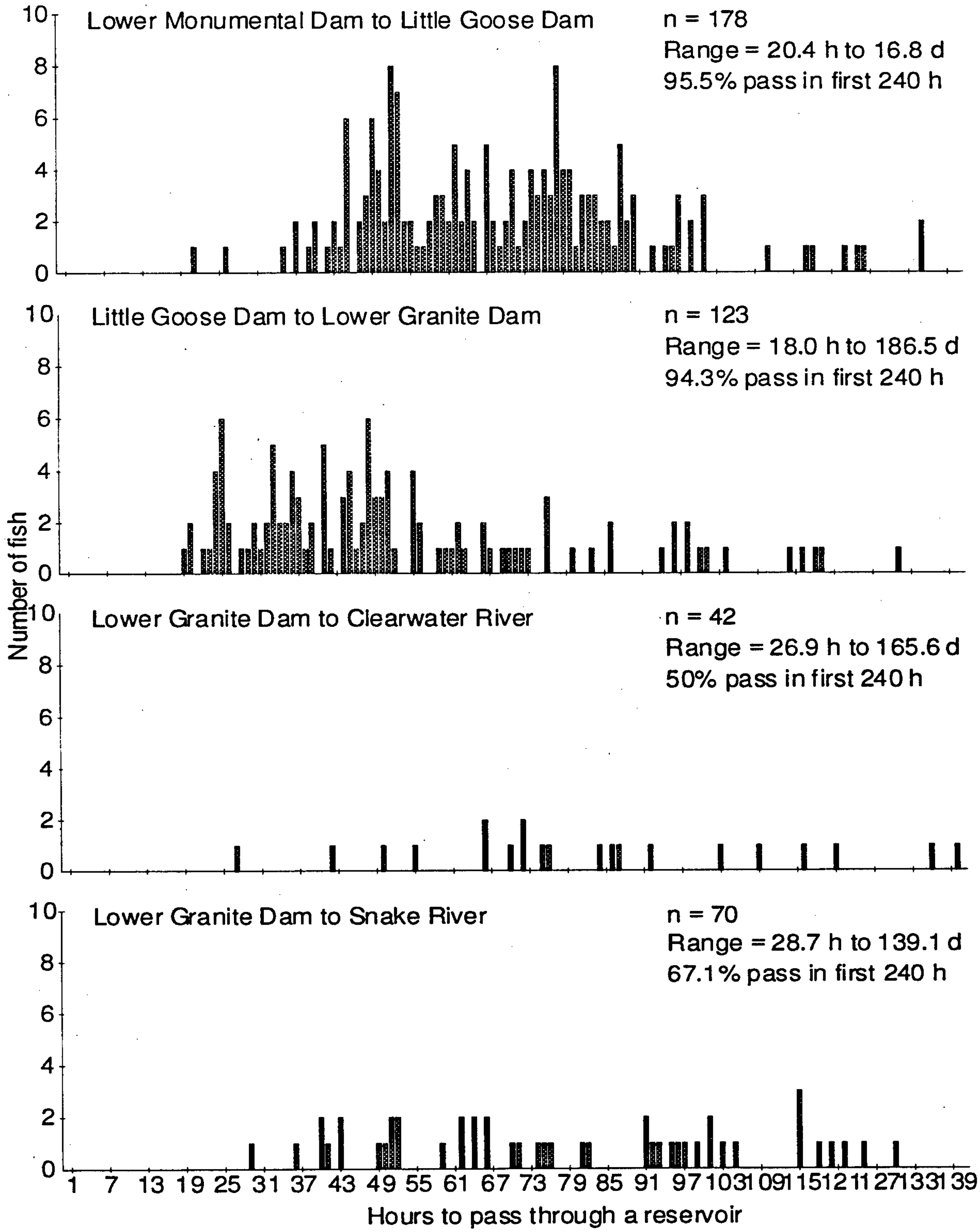



Figure 32. Frequency distribution for steelhead passing through each of the reservoirs in the lower Snake River in 1992. Steelhead released at Charbonneau Campground in the fall and migrating over Lower Granite Dam before 31 December 1992.

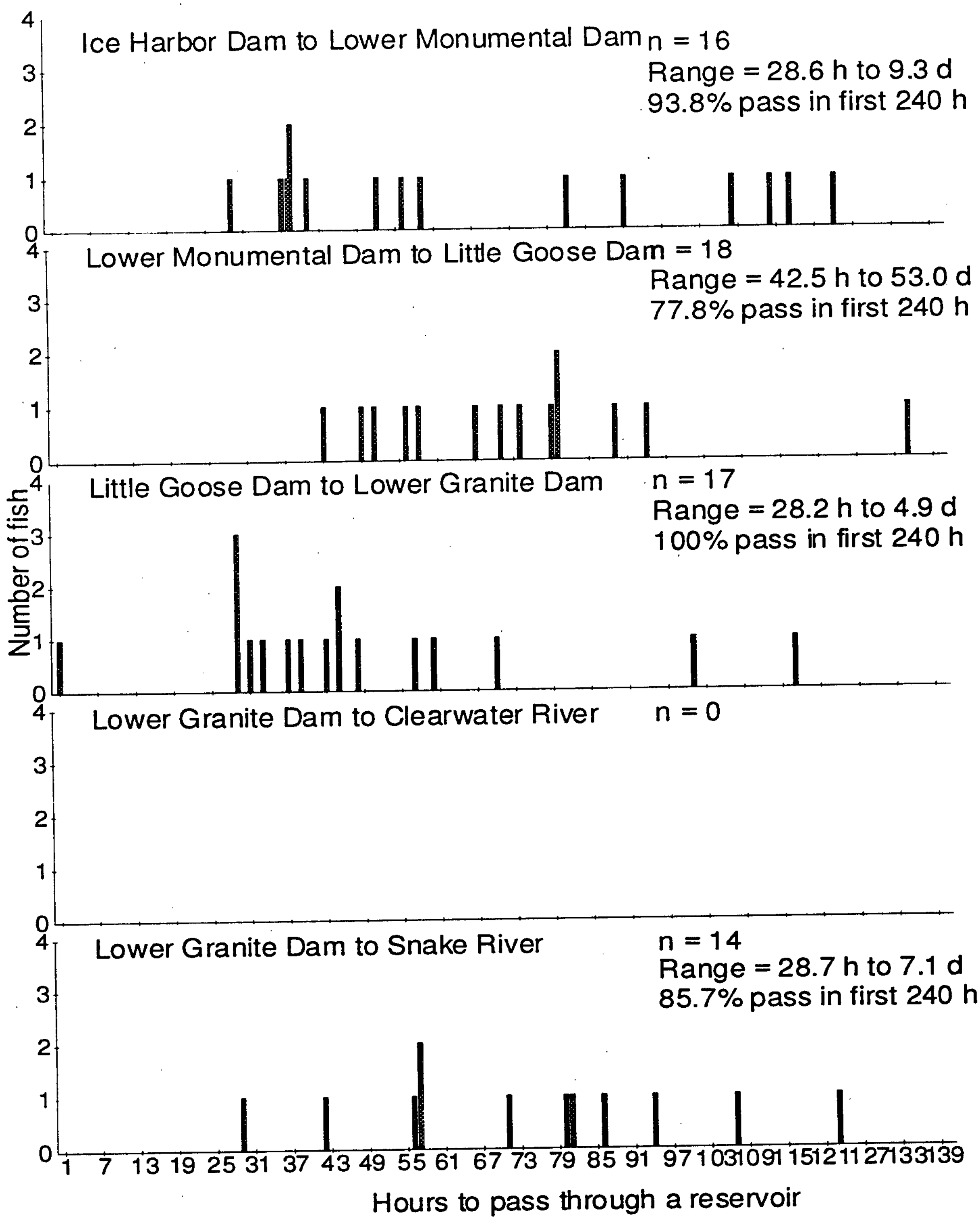



Figure 33. Frequency distribution for steelhead passing through each of the reservoirs in the lower Snake River in 1992. Steelhead released at Hood Park in July and migrating over Lower Granite Dam before 31 December 1992.

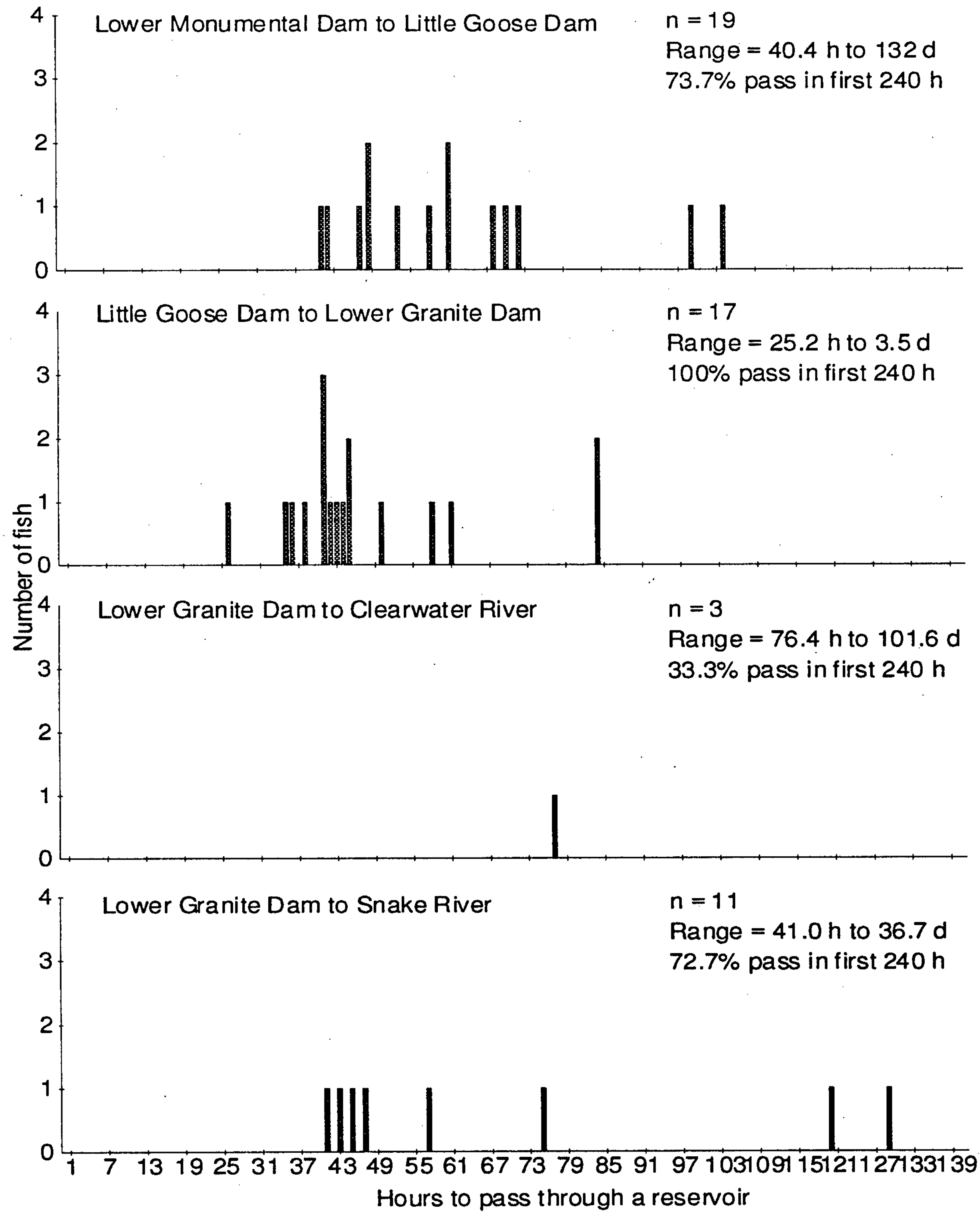



Figure 34. Frequency distribution for steelhead passing through each of the reservoirs in the lower Snake River in 1992. Steelhead released at Charbonneau Campground in July and migrating over Lower Granite Dam before 31 December 1992.

***Movements into and through the Lower Granite Dam fishway*** **-** Fishway entrance use and movements within the fishway at Lower Granite Dam were monitored in the fall of 1992 by recording movements of 356 steelhead with transmitters using the new digital spectrum processors connected to radio receivers. Antennas were placed near each entrance to the fishway, within the fishway, and at the top of the ladder (Figure 25). With the new telemetry system, it became possible to monitor the movements of individual fish with transmitters as they approached the entrances to the fishway, their movements within the fishway, and the time they took to pass the dam.

To put passage times at Lower Granite Dam into perspective, median passage time for steelhead from Hood Park to the Lower Granite Dam tailrace was 16.8 d in 1992, with similar rates to the Lower Granite trap and to pass over the dam (Figure 35). Mean passage times for the same stretches of river were about 25 d, but the mean is a less useful descriptor because of the non-normal distribution of passage times.

Median times for passage from the tailrace receiver (about 2 km downstream from the dam) at Lower Granite Dam to the first recorded approach at an entrance, first entry into the fishway, and exit from the top of the ladder were 0.14, 0.23, and 1.13 d, respectively.

The distribution of passage times were skewed to the right with a few fish taking several days to approach the entrances, enter the fishway, or pass over the dam (Figure 36). Mean passage times were longer than median times. Most of the fish entered the fishway within 6-12 hours after passing the tailrace receiver, but several fish took up to 3 d to pass the dam because they spent a day or more in the fishway or time exiting and re-entering the fishway. Some of the time spent in the fishway was at night when the fish temporarily discontinued their upstream migration, but some of the time was spent by fish migrating up and down the powerhouse collection channel during daylight (Figure 37). The passage time between the tailrace and the top of the ladder also includes the time some fish used when they exited the fishway via one of the entrances, moved out into the tailrace, and then re-entered the fishway.

Steelhead had a tendency to approach the dam first along the southern half , although more than 60 of the 353 fish recorded approached north powerhouse entrance 3 (north PH-3) first (Figure 38). Approaching the dam along the southern half was probably a response to discharge from the powerhouse being from the southern most turbine units when flows are low in the fall. However, the first approaches at north PH-3 is an indication that significant numbers of fish move up to the dam north of the powerhouse, perhaps

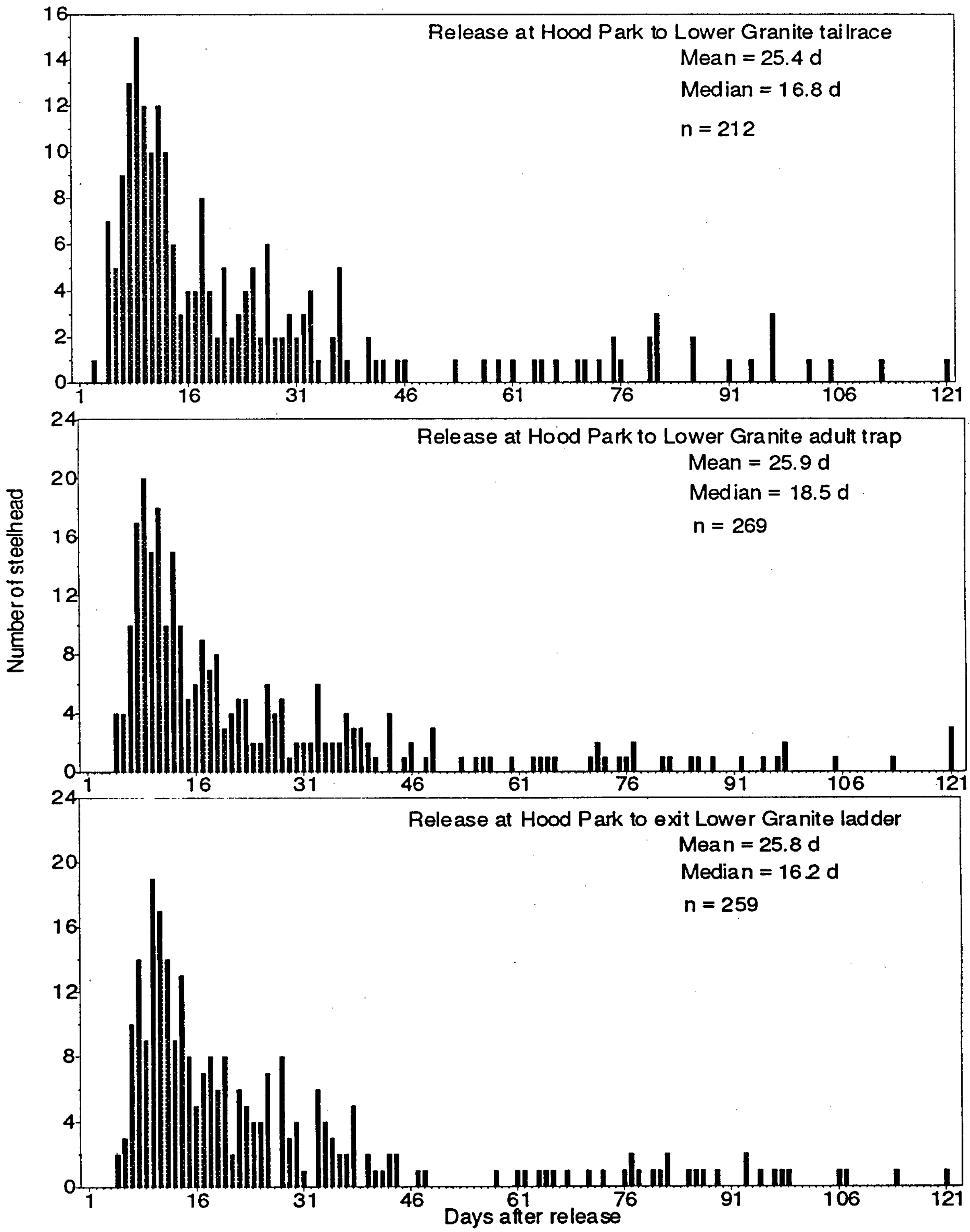



Figure 35. Distribution of number of steelhead and days to migrate to the Lower Granite Dam tailrace, adult trap, and to exit from the top of the ladder in the fall of 1992.

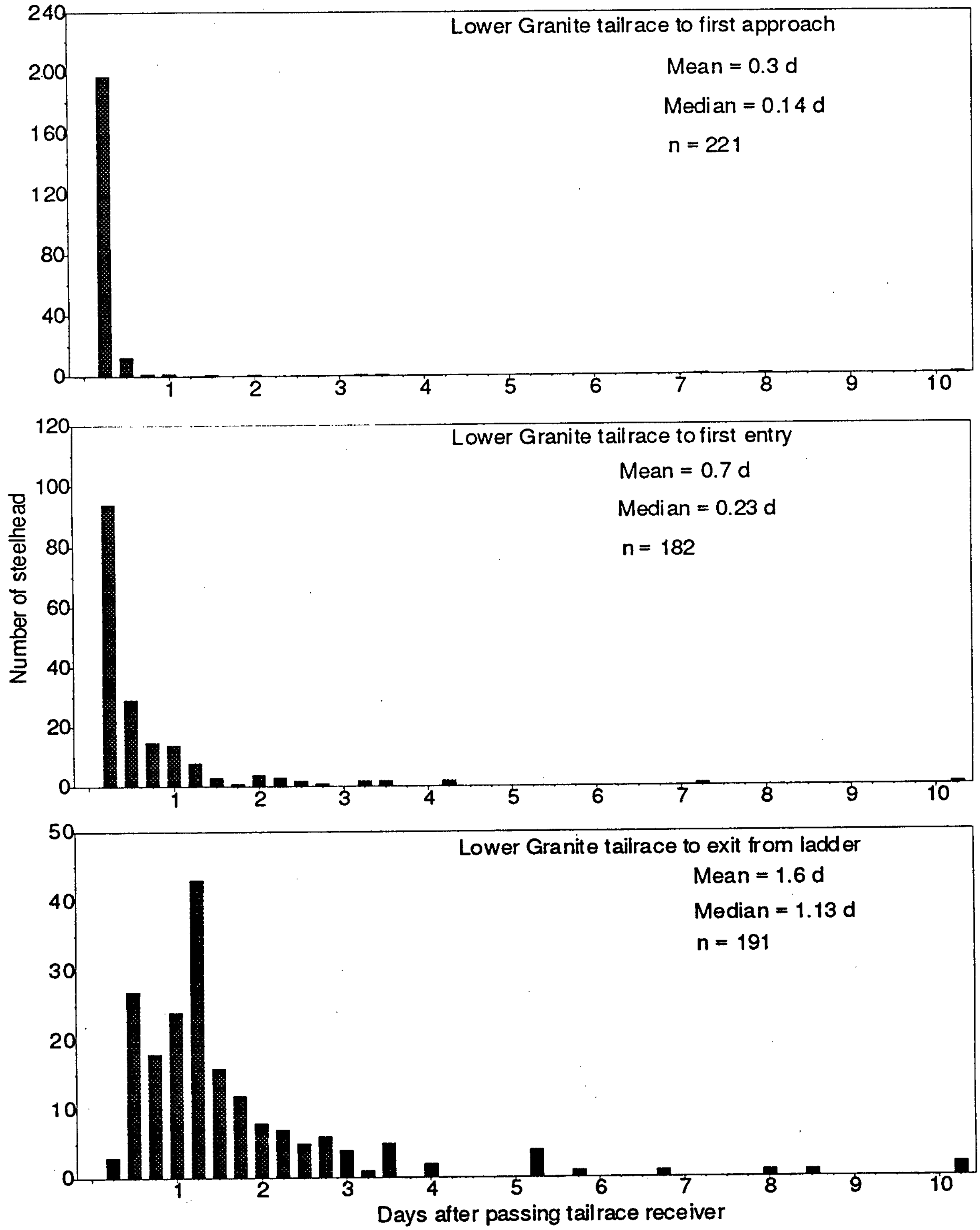



Figure 36. Distribution of numbers of steelhead and days to pass from the Lower Granite Dam tailrace to first approach at a fishway entrance, first entry into the fishway, and exit from the top of the ladder in fall 1992.

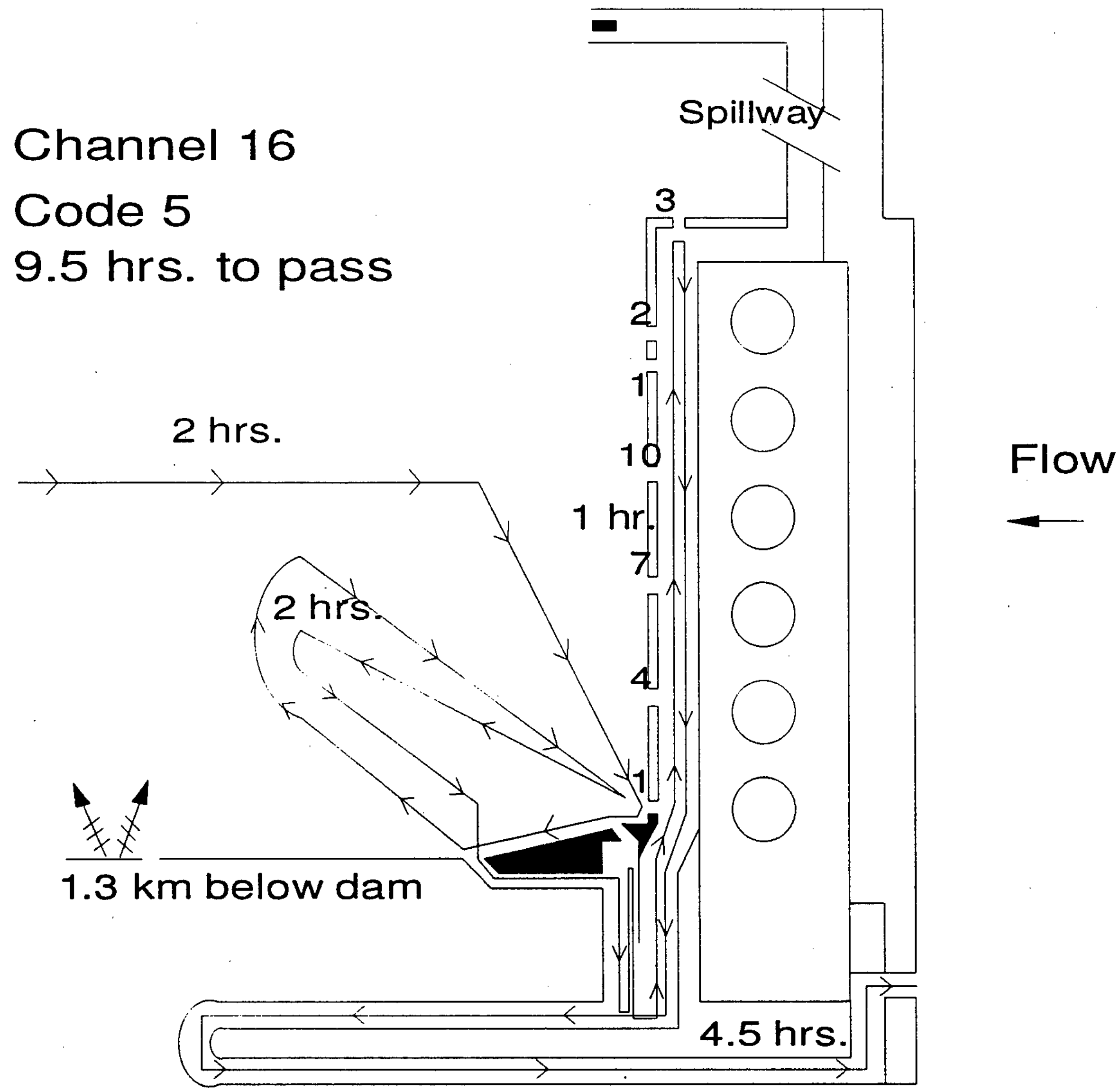
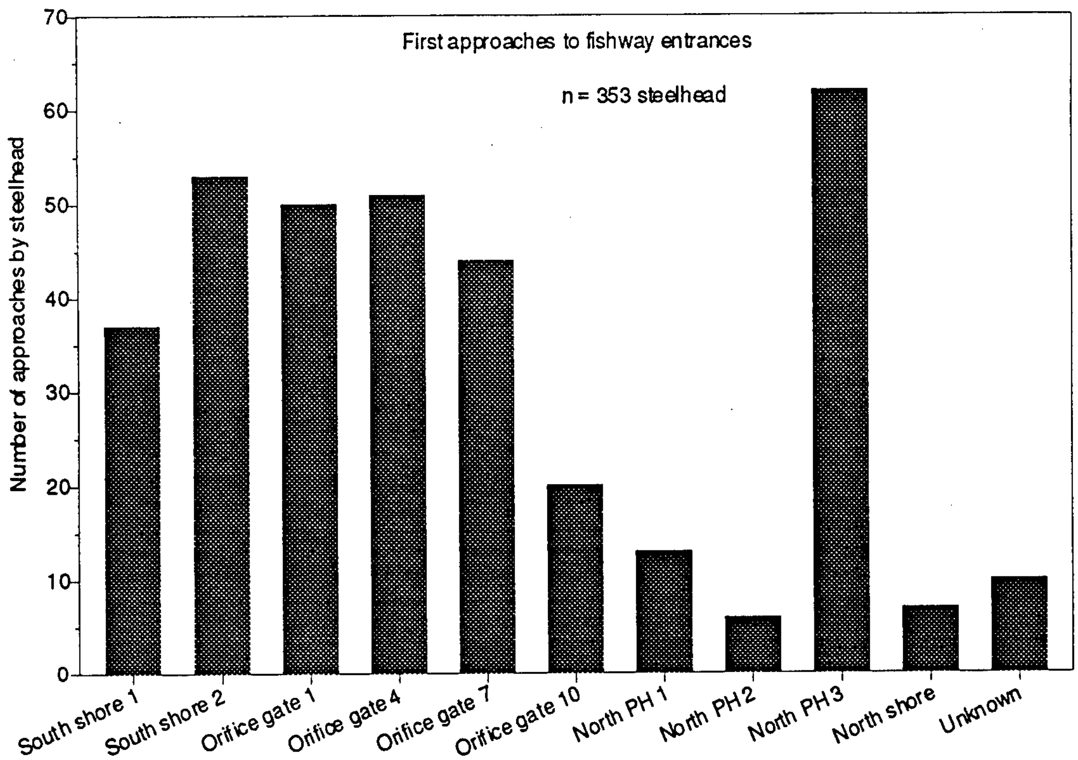



Figure 37. Diagram of Lower Granite Dam with an illustration of the types of movements made be some steelhead in the fall of 1992 when approaching the dam and passing through the fishway.

circle through the spillway stilling basin, and pass by the north PH-3 entrance before entering the fishway.

When all the approaches at fishway entrances made by steelhead in the fall of 1992 are considered, steelhead concentrated at the south end of the powerhouse at the south shore 2 entrance and at orifice gate 1 entrance (Figure 38). The large number of approaches to entrances (51 per fish on average, 18,000 total) is an indication that



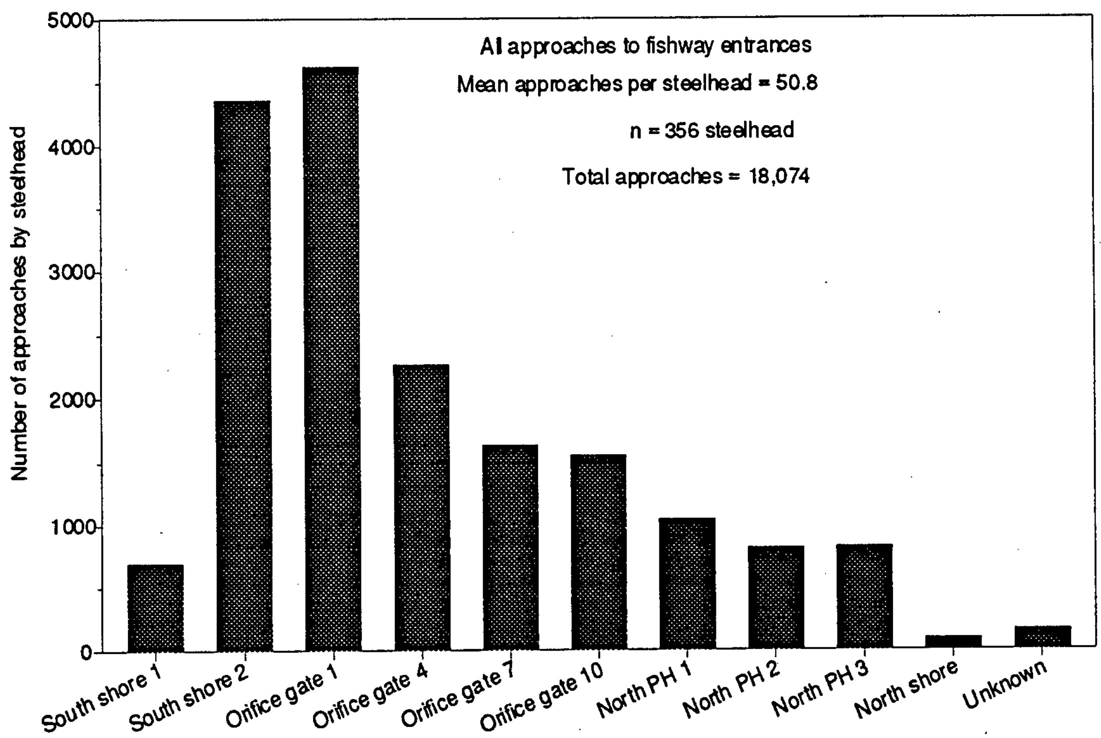




Figure 38. Number of first and total approaches at fishway entrances at Lower Granite Dam by steelhead in the fall of 1992.

steelhead were somewhat hesitant to enter the fishway and moved back and forth along the dam before entering the fishway. About 17% of the 356 steelhead monitored, had approached the dam 10 or fewer times, with several fish approaching various entrances 50 or more times (Figure 39). Although steelhead moved back and forth along the dam and approached the entrances several times, the time between first approach and first entry into the fishway was only about three hours (based on median passage times, Figure 36). Since 1992 was the first year we were able to collect reliable time of passage information on a large number of fish, we do not know if three hours median time to enter a fishway after first approach is normal or if it is something to be concerned about.

The entrances to the fishway used by steelhead in the fall of 1992 were more restricted than the entrances approached. For example, a majority of the first and repeated entries into the fishway occurred at the south shore-2, north PH-3, and north shore entrances (Figure 40), whereas many of the first approaches at the dam were at the floating orifice-gate entrances in addition to the most used entrances (Figure 38). Although many fish approached the orifice-gate entrances, relatively few entered the fishway through those openings. The location of discharges from the dam was an important factor in where fish approached the dam, but not the only factor as illustrated by the higher than average numbers of fish that approached the dam and entered the fishway at the north PH-3 and north shore entrances where there was no flow to attract the fish other than that coming from the fishway. The discharges from the north PH-3 and north shore entrances may have been easier for steelhead to find and follow to the entrances because the discharges were into the spillway stilling basin when there was no spill. The relatively low use of the orifice-gate entrances may have resulted because discharges (design of 60 cfs) from those entrances mixed with the discharges from the turbines, the discharge was not attractive to the fish (volume and velocity), and the size and depth of the orifice-gate openings may not have been as attractive as other openings. The orifice gate entrances at Lower Granite Dam are 2 feet high and 6 feet wide, with the top of the opening 3 feet down from the water surface. South shore entrance-2 is a vertical slot with an 8 foot water depth.

Most steelhead (226 of 356 monitored, 64%) entered the fishway at Lower Granite Dam only once (Figure 41). About one-third of the fish entered two or more times. Two-thirds of the steelhead that entered the fishway did not exit the fishway through any of the entrances, and the remainder exited the fishway 1 to13 times.

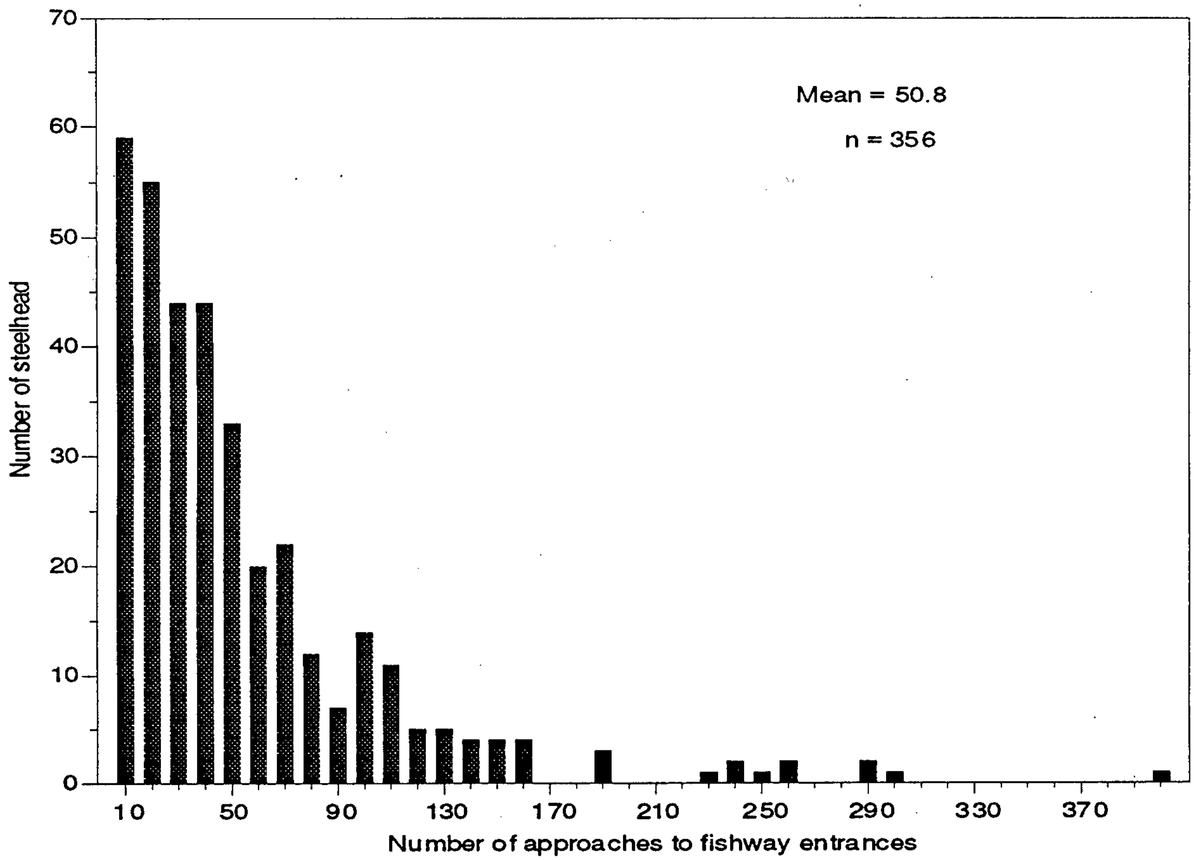



Figure 39. Number of steelhead approaching fishway entrances one or more times at Lower Granite Dam in fall 1992.

Steelhead exited from the fishway via all of the entrances, but more did so at the north PH-1 and south shore-1 entrances (Figure 42). The number of fish exiting from the fishway at the north PH-1 entrance was probably increased by the fishway fence that was installed to reduce the number of fish that left the fishway via the north PH-1 and -2 entrances. A high exit rate had been observed at the north powerhouse entrances (Turner et al. 1982; 1983) and the fence was installed to guide fish migrating upstream in the collection channel past the two entrances. From the 1992 studies, we found that many fish moved downstream in the collection channel and if they moved as far as the north end of the powerhouse and were on the tailrace side of the channel, the fence would guide them to the north powerhouse entrance, just the opposite of the intended purpose of the fence.

Net entry rates (entrances minus exits) for the fishway entrances ranged from about 100 to -9 for first entries and exits, and 170 to -20 for all entries and exits (Figure 43). The south shore-2 entrance was the most effective entrance followed by north PH-3, north shore, and orifice gate-1. There were more exits than entries of steelhead at the south

shore-1 and north PH-1 and -2 entrances. Entries exceeded exits by a small margin at orifice-gate entrances 4, 7, and 10.

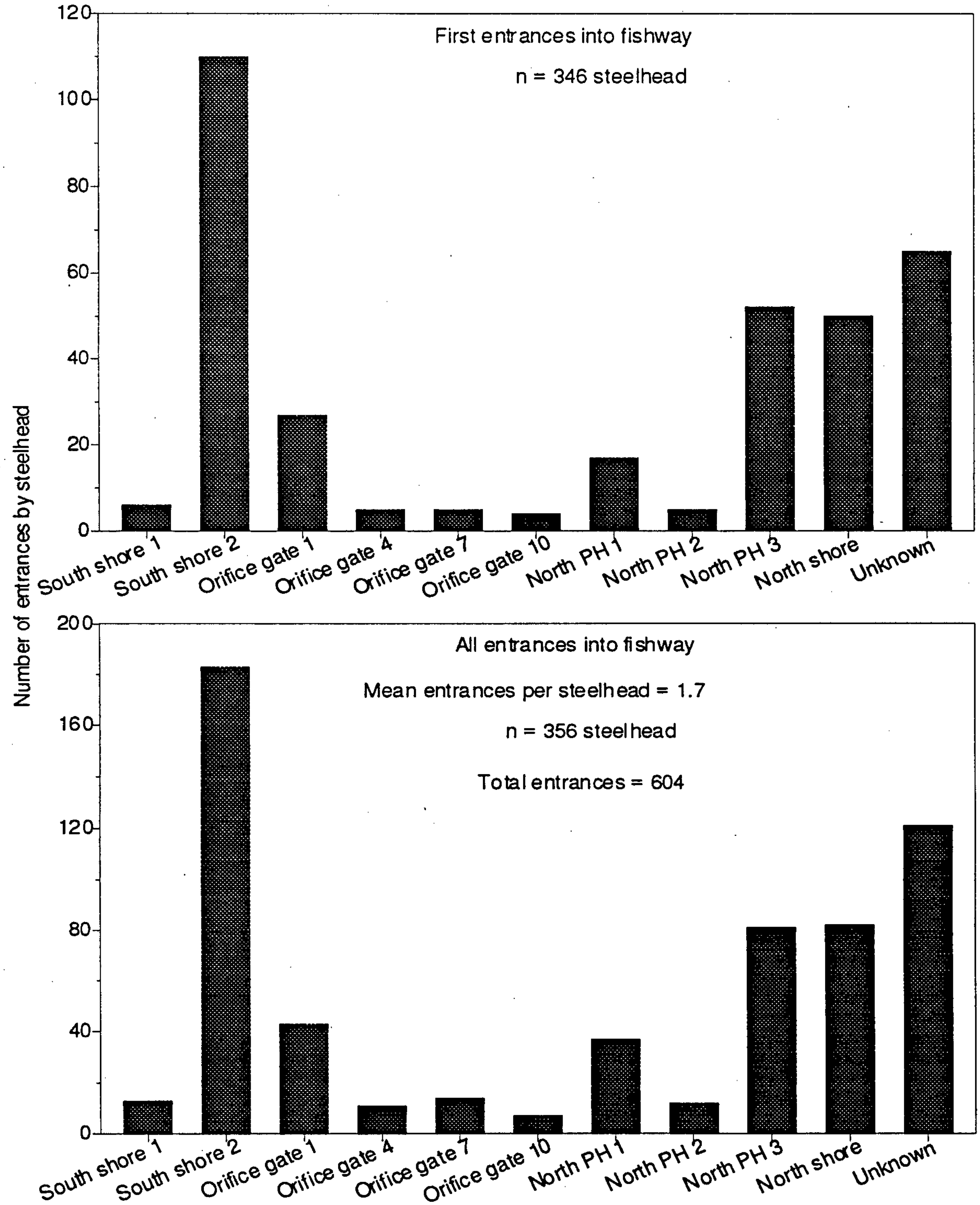



Figure 40. Number of first and total entries by steelhead into the Lower Granite Dam fishway via each entrance in fall 1992.

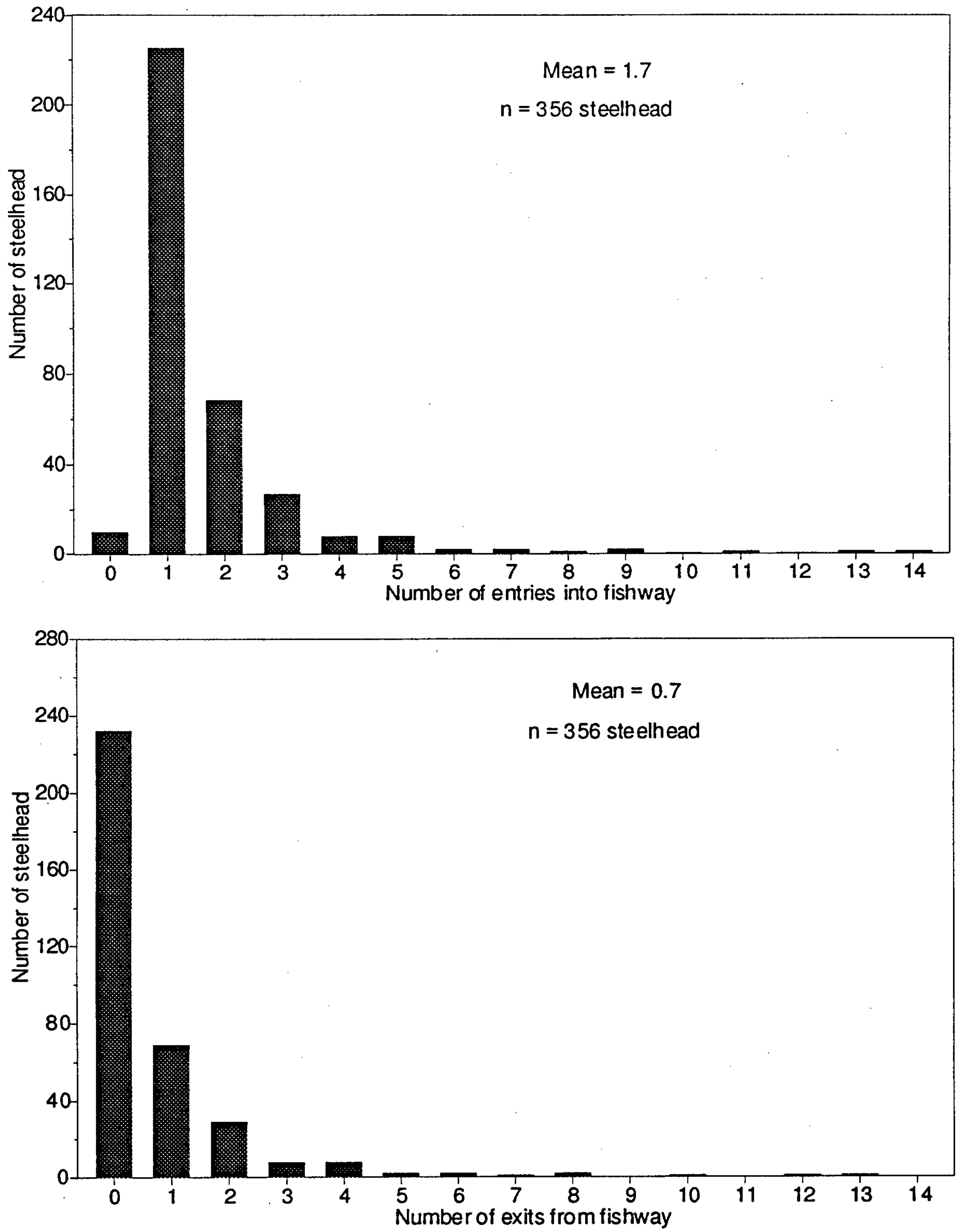
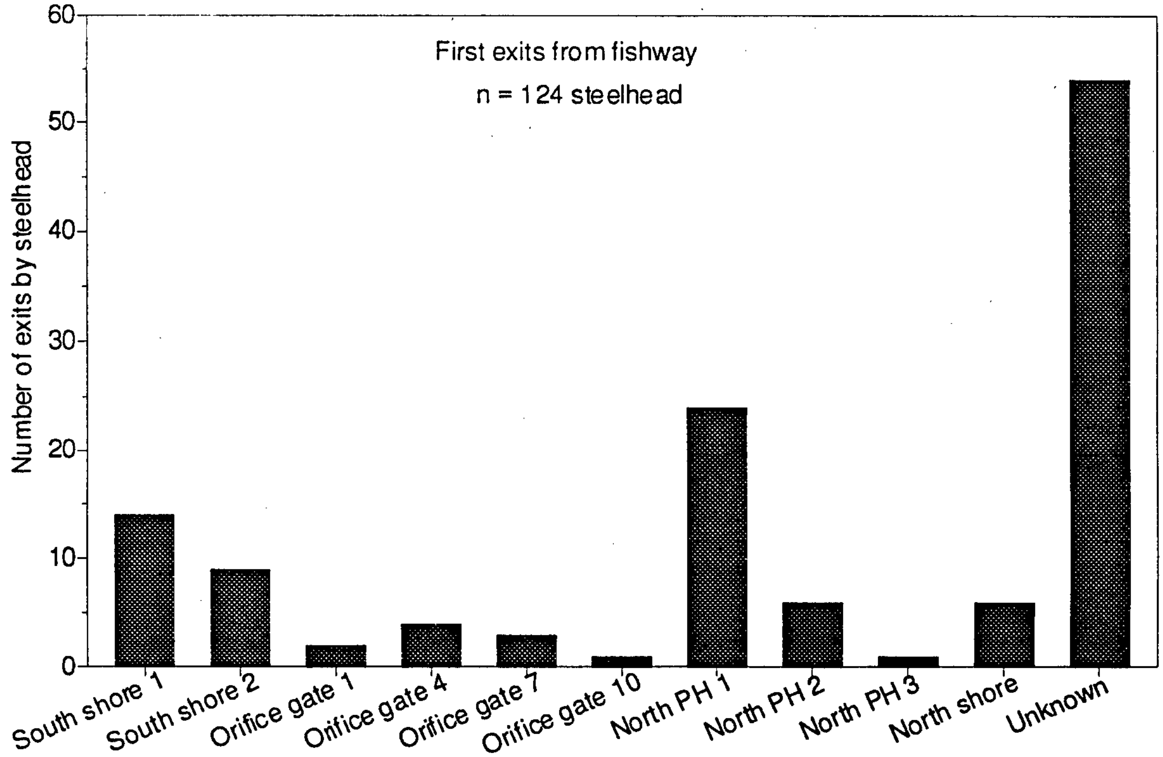



Figure 41. Number of steelhead that did not enter or exit, and those with multiple entries and exits into or from the fishway at Lower Granite Dam via the entrances in fall 1992.



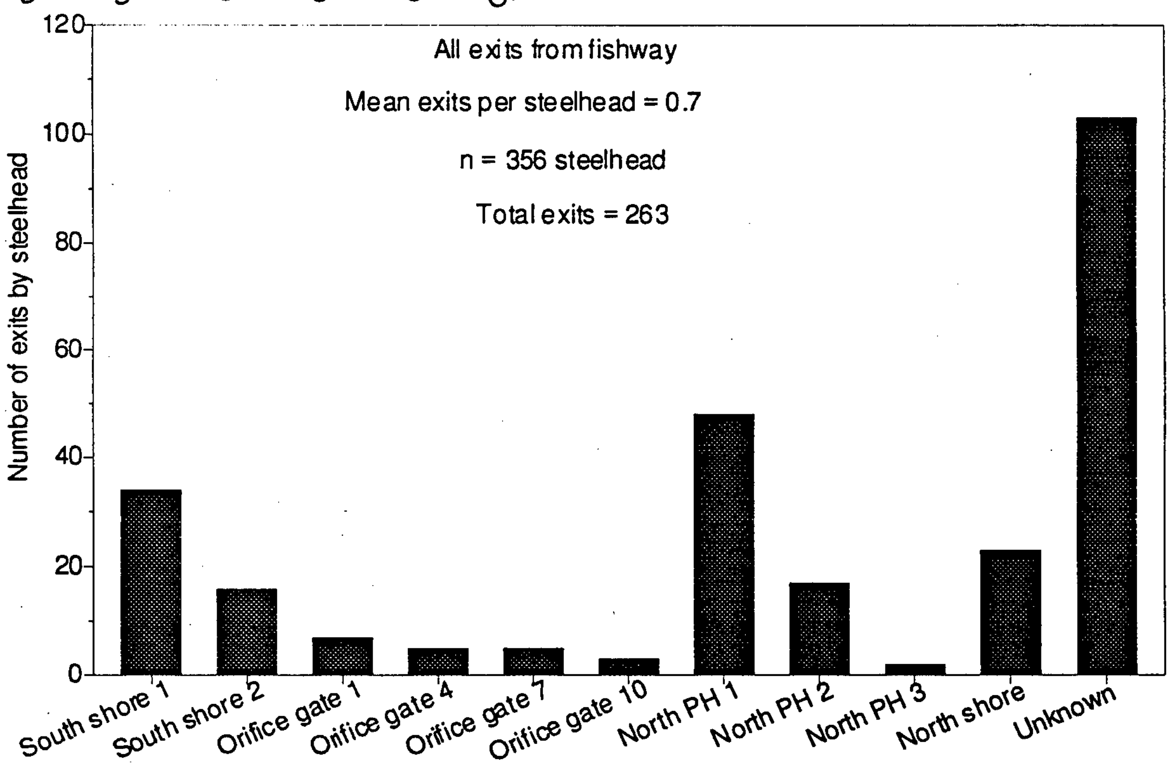




Figure 42. Number of first and total exits from fishway for each entrance by steelhead at Lower Granite Dam in fall 1992.

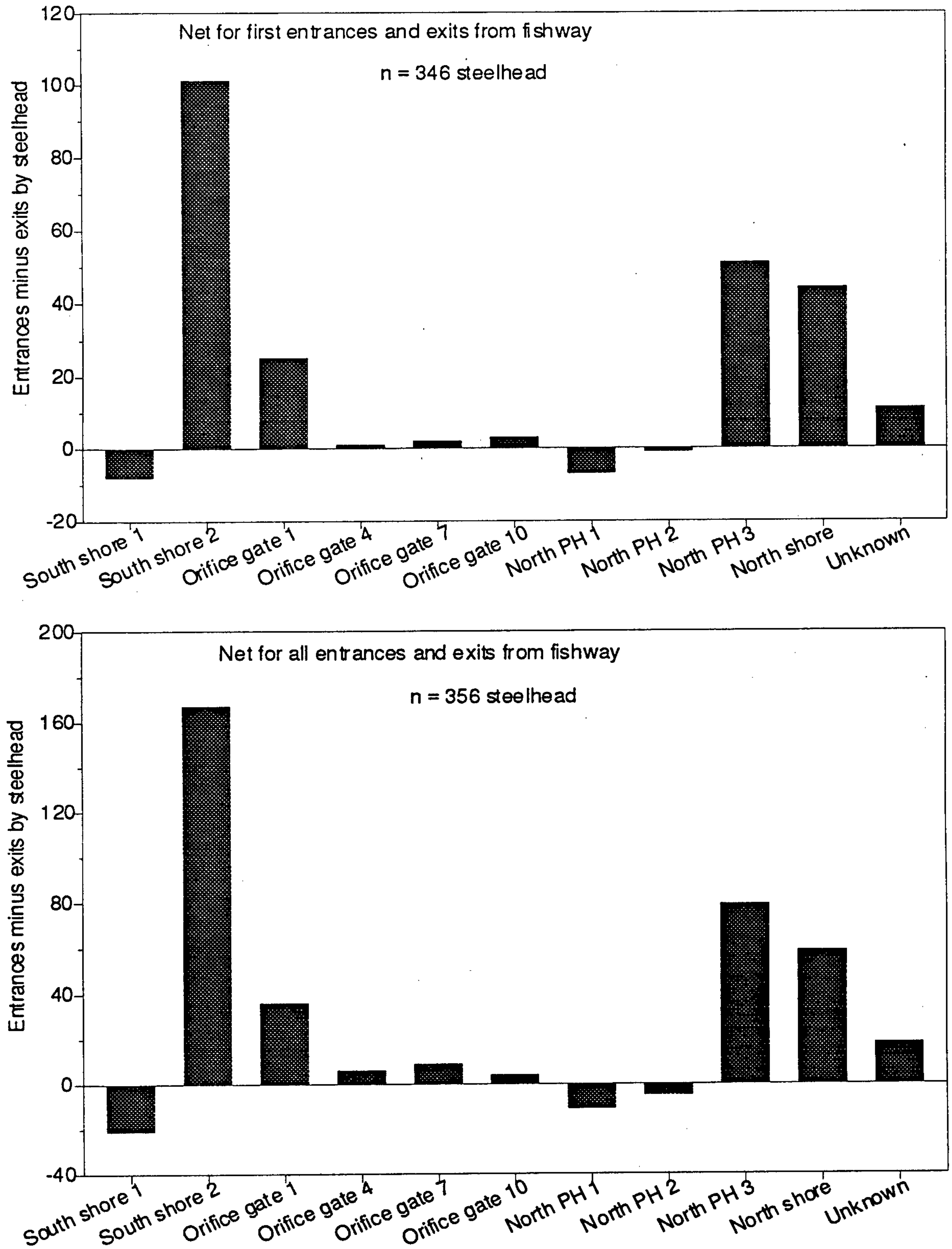



Figure 43. Net number of first and total exits from fishway for each entrance by steelhead at Lower Granite Dam in fall 1992.

***Use of north powerhouse entrances at Lower Granite Dam.-*** In the fall of 1992, we monitored steelhead use of the three entrances to the fishway at the north end of the powerhouse at Lower Granite Dam to determine which combination of the three entrances were the most effective as entrances. Steelhead with transmitters were monitored as they entered and exited the three entrances as described in previous sections where we used the digital spectrum processor and receivers. Normally only two of the three entrances are opened at the same time because of flow limitations in the collection channel. A schedule was set up starting in early September with a rotation of entrance openings, north PH-1 and -2, north PH-1 and -3, and north PH-2 and -3 (Figure 44). In early October, a camera used in video monitoring of entrance use in 1992 malfunctioned in north PH-2, and it was necessary to close that entrance for a time which disrupted the scheduled north PH-1 and -2 combination of openings.

The north PH-3 entrance that opens into the spillway stilling basin was the most effective of the three openings for fish entries and exits (Table 16). The ratio of fish entering the fishway through north PH-3 versus north PH-1 or -2 was 5.4:1 for the two combinations together. The ratio of entries to exits was even more in favor of north PH-3 with only 1 fish leaving the fishway via that entrance compared to 37 exits for north PH-1

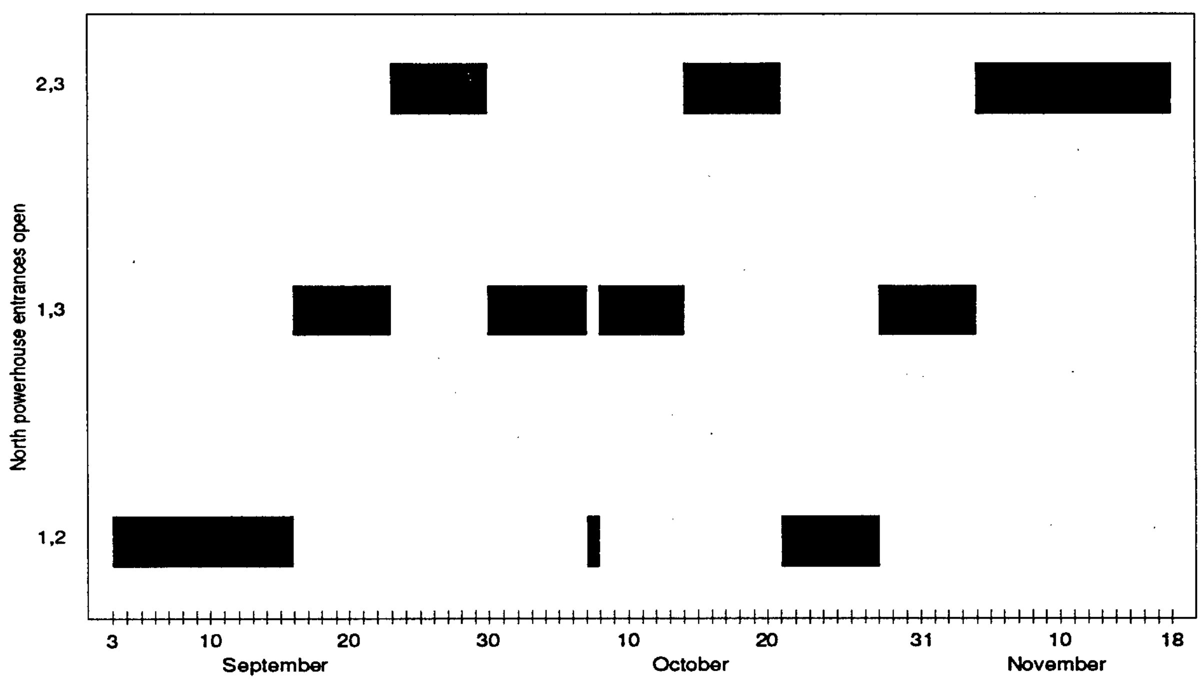



Figure 44. Schedule of open periods (black boxes) for north powerhouse entrances at Lower Granite Dam in fall 1992.

and -2 when open with north PH-3. When north PH-1 and -2 were open, about equal numbers of fish entered and exited each entrance. During the period of testing, 283 steelhead with transmitters entered or exited the fishway at all entrances, and 114 used one or more of the north powerhouse entrances.

Table 16. The number of entries and exits at the three north powerhouse entrances (north PH-1, -2, -3) by steelhead with transmitters at Lower Granite Dam in fall 1992, number of fish using the north powerhouse entrances, and all entrances to the fishway during period of testing, and ratios of entries to exits for north PH-3 versus PH-1 or -2. Discharge from the powerhouse was though turbine units 1 and 2 during testing.

| Activity and entrance | North powerhouse entrances open: | | |
|---|---|---|---|
| | 1 and 2 | 2 and 3 | 1 and 3 |
| Entries | | | |
| North PH-1 | 6 | --- | 9 |
| North PH-2 | 9 | 3 | --- |
| North PH-3 | --- | 27 | 38 |
| Totals | 15 | 30 | 47 |
| Exits | | | |
| North PH-1 | 8 | --- | 28 |
| North PH-2 | 7 | 9 | --- |
| North PH-3 | --- | 1 | 0 |
| Totals | 15 | 10 | 28 |
| Fish using north PHs | 21 | 34 | 59 |
| Fish using all entrances | 57 | 116 | 110 |
| Entries:Exits | 1:1 | 3:1 | 1.7:1 |
| Ratios of north PH-3 : PH-1 or -2 | | | |
| Entries | --- | 9:1 | 4.2:1 |
| Exits | --- | 1:9 | 0:28 |

***Recaptures of steelhead tagged in 1992.-*** Of the 3,414 steelhead outfitted with transmitters or tagged with spaghetti-loop tags in 1992, reports were returned to us for 975. Of the 975 fish, 748 had been taken in fisheries, 227 recaptured at hatcheries, and 27

found dead in the rivers (Table 17). In addition, 2,405 of the tagged fish (70%) were recaptured in the Lower Granite trap from July 1992 through 1 March 1994.

Of the 748 steelhead reported caught in fisheries during the fall of 1992 and spring of 1993, 51 were fish that had moved downstream into the Columbia River after release and were caught there or in tributaries downstream from the Snake River (Table 17). A total of 57 steelhead (5.6% of those recaptured, excluding recaptures at the Lower Granite trap) were recorded as having moved downstream into the Columbia River after tagging and release, with 3 fish trapped at weirs, 3 fish found dead, and 51 caught in fisheries.

The largest number of recoveries (254; 27.2% of the recaptured fish, Table 17) for a reach of river, was from the lower Snake River (mouth to Lewiston) where 214 steelhead were caught by anglers from the Snake River, 23 were caught from the Tucannon River, 3 were taken in traps, and 14 were found dead.

Eighty steelhead were reported taken by anglers from the Snake River between Lewiston and the Salmon River, 18 fish were taken upstream from the Salmon River, and 21 trapped at Hells Canyon Dam, for a total of 119 fish (11.9% of the recaptures, Table 17).

In the Clearwater River basin, 130 steelhead were reported caught from the main stem Clearwater River, and 12 from the North Fork (Table 17). In addition, 103 of the tagged steelhead entered Dworshak NFH, 2 at a trap in the upper tributaries, and 8 were found dead, for a total of 257 fish (25.5% of the recaptures).

Sixty-six steelhead (6.5% of recaptures) were reported as recaptures in the Grande Ronde River basin with 41 taken in the fishery and 25 into hatcheries (Table 17). Thirty-two recaptured steelhead were reported from the Imnaha River basin, with 6 taken in the fishery and 26 trapped at the Little Sheep Creek weir.

Anglers fishing the Salmon River reported catching 171 tagged steelhead, 1 was found dead, 2 were recovered from spawning grounds, 4 were taken at Rapid River SFH, 28 were taken at Pahsimeroi SFH, and 17 at Sawtooth SFH, for a total of 223 recaptures (22.1% of recaptures, Table 17).

In 1992, 55% of the 694 steelhead released with transmitters were wild fish and the remainder were classified as hatchery fish on the basis of fin clips. Of 122 steelhead with transmitters reported by anglers as being caught, 27 (22%) were wild fish of which 6 were

Table 17. Recaptures of the 694 steelhead with transmitters and the 2,342 fish tagged with spaghetti-loop tags and released at Hood Park or Charbonneau campgrounds near Ice Harbor Dam in 1992. Recaptures occurred from July 1992 through May 1993.

| Recapture location | Type of recapture | Number of fish |
|---|---|---|
| Columbia River | | |
| Upstream from Snake River | Fishery | 9 |
| | Found dead | 2 |
| Downstream from Snake River | Fishery | 27 |
| | Trap | 1 |
| Walla Walla River | Fishery | 13 |
| | Found dead | 1 |
| Umatilla River | Fishery | 1 |
| | Weir | 2 |
| Touchet River | Fishery | 1 |
| | Subtotal | 47 |
| Snake River | | |
| Mouth to Lewiston | Fishery | 214 |
| | Found dead or tags | 14 |
| Lyons Ferry Hatchery | Trap | 2 |
| Tucannon River | Fishery | 23 |
| | Hatchery | 1 |
| Lower Granite Adult Trap | Trap | 2,405 |
| Lewiston to Salmon River | Fishery | 80 |
| Salmon River to Hells Canyon Dam | Fishery | 18 |
| Hells Canyon Dam | Trap | 21 |
| Clearwater River | Fishery | 130 |
| | Found dead | 5 |
| North Fork | Fishery | 12 |
| Dworshak Fish Hatchery | Trap | 103 |
| Kooskia Fish Hatchery | Trap | 0 |
| Upper Clearwater and tributaries | Trap | 2 |
| | Found dead | 3 |
| Grande Ronde River | Fishery | 31 |
| Big Canyon Creek trap | Trap | 7 |
| Catherine Creek | Fishery | 1 |
| Wallowa River | Fishery | 9 |
| | Trap | 18 |
| Imnaha River | Fishery | 6 |
| Little Sheep Creek | Trap | 26 |

Table 17. Continued.

| Recapture location | Type of recapture | Number of fish |
|---|---|---|
| Salmon River | Fishery | 170 |
| | Found dead | 3 |
| Rapid River | Trap | 4 |
| Pahsimeroi River | Fishery | 1 |
| Pahsimeroi Fish Hatchery | Trap | 28 |
| Sawtooth Fish Hatchery | Trap | 17 |
| | Total | 3,414 |
| | Hatcheries | 227 |
| | Fisheries | 748 |

kept, 18 were released, and the disposition of 3 fish was unknown. Of the 95 hatchery steelhead with transmitters reported caught by anglers, 75 were kept, 3 were reported released, and the disposition of 17 fish was unknown.

Steelhead released with spaghetti-loop tags for the zero-flow test in 1992 were also caught by anglers, but they were all hatchery fish. Of the 616 fish reported caught, 443 were kept, 17 were released, and the disposition of 156 fish was unknown.

***Distribution of steelhead outfitted with transmitters in 1992.-*** The 694 Steelhead outfitted with transmitters in 1992 were tracked as they migrated past the dams and into the tributaries of the Snake River through the end of the spawning period in May of 1993. The distribution of those fish based on last sitings at fixed-site receivers, by mobile tracking, and by recaptures by anglers, at weirs and hatcheries is presented in Table 18. Twenty-five of the 694 (3.6%) fish released with transmitters were not located again; 15 of the 25 were fish released at Hood Park, and 10 were released at Charbonneau Campground.

Eighty-six (12.4%) of the released fish were last located back downstream in the Columbia River or in tributaries (Table 18). Thirty-seven of the fish were found in the Columbia River upstream from the Snake River, and 38 were found downstream, and 11 were found in tributaries (1 in the Touchet, 7 in the Walla Walla, 2 in the Umatilla, and 1 in the Yakima rivers).

Table 18. Distribution of 694 steelhead released with transmitters in 1992 based on last sitings at receivers or by mobile tracking, and recaptures by anglers, at weirs, or at hatcheries.

| Location of last siting | Number of fish | Percent of recaptures |
|---|---|---|
| Release sites near Ice Harbor Dam | | |
| Hood Park | 15 | 2.1 |
| Charbonneau Campground | 10 | 1.4 |
| Columbia River | | |
| Upstream from Snake River | 37 | 5.3 |
| Downstream from Snake River | 38 | 5.5 |
| Walla Walla River | 7 | 1.0 |
| Touchet River | 1 | 0.1 |
| Umatilla River | 2 | 0.3 |
| Yakima River | 1 | 0.1 |
| Lower Snake River | | |
| Downstream from Ice Harbor Dam | 10 | 1.4 |
| Ice Harbor Dam and Reservoir | 47 | 6.8 |
| Lower Monumental Dam and Reservoir | 58 | 8.4 |
| Lyons Ferry Hatchery | 0 | 0.0 |
| Tucannon River | 4 | 0.6 |
| Little Goose Dam and Reservoir | 20 | 2.9 |
| Lower Granite Dam and Reservoir | 89 | 12.8 |
| Lower Granite adult trap | 0 | 0.0 |
| Clearwater River drainage | | |
| Receiver site near mouth | 19 | 2.7 |
| Clearwater River, mouth to North Fork | 66 | 9.5 |
| Clearwater River, North Fork to Lowell | 19 | 2.7 |
| Dworshak National Fish Hatchery | 21 | 3.0 |
| Kooskia National Fish Hatchery | 0 | 0.0 |
| North Fork of Clearwater River | 5 | 0.7 |
| Orofino Creek | 1 | 0.1 |
| Lolo Creek | 1 | 0.1 |
| Lochsa River | 13 | 1.9 |
| Selway River | 12 | 1.7 |
| South Fork of Clearwater River | 9 | 1.3 |
| Snake River upstream from Lewiston | | |
| Lewiston to Salmon River | 79 | 11.4 |
| Salmon River to Hells Canyon Dam | 4 | 0.6 |
| Grande Ronde River drainage | | |
| Receiver site near mouth | 6 | 0.9 |
| Grande Ronde River | 7 | 0.9 |
| Wallowa River | 4 | 0.6 |
| Bear Creek | 1 | 0.1 |

Table 18. Continued.

| Location of last siting | Number of fish | Percent of recaptures |
|---|---|---|
| Imnaha River drainage | | |
| Imnaha River | 1 | 0.1 |
| Imnaha River weir | 2 | 0.3 |
| Salmon River drainage | | |
| Salmon River, mouth to Riggins | 24 | 3.5 |
| Little Salmon River | 6 | 0.9 |
| Rapid River trap | 1 | 0.1 |
| Salmon River, Riggins to South Fork | 19 | 2.7 |
| South Fork of Salmon River | 6 | 0.9 |
| Salmon River, South Fork to Middle Fork | 1 | 0.1 |
| Receiver at mouth of Middle Fork | 7 | 1.0 |
| Marsh Creek | 1 | 0.1 |
| Salmon River, Middle Fork to North Fork | 7 | 1.0 |
| Receiver at North Fork | 3 | 0.4 |
| Salmon River upstream from North Fork | 9 | 1.3 |
| Pahsimeroi River | 1 | 0.1 |
| East Fork of Salmon River | 1 | 0.1 |
| Totals | 694 | 100.0 |

Within the Snake River, 10 of the steelhead were last recorded downstream from Ice Harbor Dam, and another 47 were last recorded at the dam or in the reservoir upstream from the dam. Lower Monumental Dam and Reservoir were the sites of last recordings for 58 steelhead, Little Goose Dam and Reservoir for 20 fish, and Lower Granite Dam and Reservoir for 89 fish (Table 18). Four fish were located in the Tucannon River. A total of 228 steelhead (32.9% of those released) were last located in the lower Snake River, downstream from the receiver sites on the lower Clearwater River and Snake River upstream from Lewiston. Several of the fish were harvested by anglers.

Of the 355 steelhead last located upstream from Lower Granite Reservoir, 166 (46.8%) entered the Clearwater River, and 189 proceeded up the Snake River upstream from Lewiston (Table 18). Of those last recorded in the Clearwater drainage, 21 entered Dworshak NFH, and the remainder of the last sitings were scattered along the main stem (104 fish) and in the main tributaries (9 fish in the South Fork, 13 in the Lochsa, 12 fish in the Selway rivers).

Of the 189 steelhead that migrated up the Snake River, 83 were last sited in the Snake River from Lewiston upstream to Hells Canyon Dam, 18 entered the Grande Ronde drainage, 3 entered the Imnaha River, and 86 entered the Salmon River (Table 18). Within the Salmon River drainage, 54 of the steelhead were last recorded in the main stem from the mouth upstream to North Fork, 7 entered the Little Salmon River, 6 entered the South Fork, 8 likely entered the Middle Fork, and 11 were found in streams upstream from North Fork.

## Steelhead - 1992 Zero-Flow Test

The test to assess the effects of reducing flows at night to near zero in the lower Snake River on steelhead migrations was continued in September through November 1992. The effects of zero flow at night on steelhead in the lower Snake River was evaluated by monitoring the migrations of the fish with transmitters, and more importantly, the five groups of steelhead tagged with spaghetti-loop tags and released at Charbonneau Campground at the start of each of the five two-week periods with either zero or normal flow at night.

### *Methods - Steelhead with Spaghetti-Loop Tags*

The zero-flow test began on 8 September in 1992 when river temperatures had declined enough that steelhead began to enter the Snake River in large numbers. The first two-week period ran from 8 to 21 September; flows were maintained at a minimum of 11.5 kcfs at Lower Granite, Little Goose, and Lower Monumental dams from about 2300 to 0500 hr each night; and 501 fish were captured, tagged with both a spaghetti-loop (orange color) and jaw tag, and released upstream from Ice Harbor Dam at Charbonneau Campground during the first six d of the period (Figure 45). The next four two-week periods alternated from zero flow at night, to normal flow at night, to zero flow, to normal flow. About 500 steelhead were tagged (different color for each period) and released at the start of the first four periods, and 300 at the start of the fifth period.

The flows at night during the zero-flow portions of the test, were decreased at the three upper dams to near zero by shutting down all turbines (ladder flows, and lockages maintained a small flow at each dam) starting about 2300 hr and continuing until about

0500 hr for each two-week period (Figures 46 and 47). Normal flows consisted of nighttime flows of about 11.5 kcfs during each two-week period.

Migrations of the steelhead tagged for the zero-flow study were monitored by: (1) the people counting fish at all four dams (number of fish with each color of loop tag by day); (2) recaptures at the adult trap in the Lower Granite Dam ladder; (3) date, time, and location of recapture in the fisheries; (4) date and number recaptured at hatcheries from each group; and (5) the movements of fish with radio transmitters during the zero and normal flow periods.

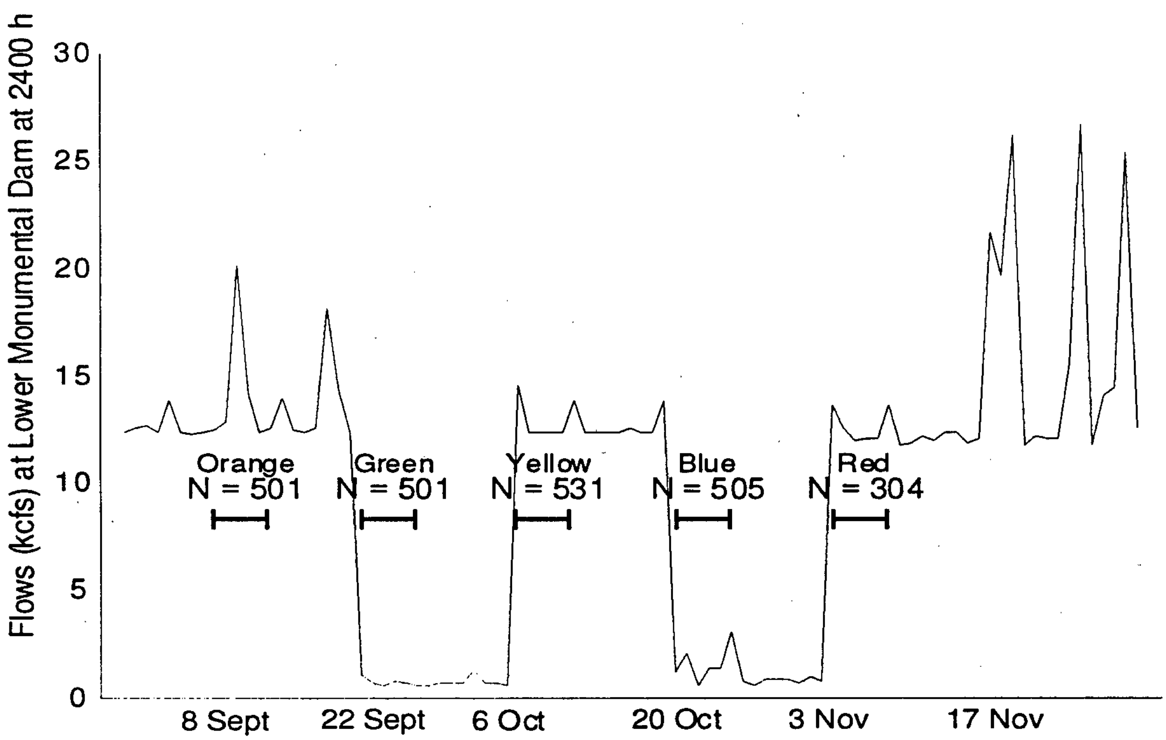



Figure 45. Pattern of flow at night at Lower Monumental Dam during the 1992 zero-flow test, the numbers of steelhead tagged with spaghetti-loop tags and released during the first five d of the five two-week test periods, and the color of tag used.

### *Results - Steelhead with Spaghetti-Loop Tags*

Two types of data on steelhead movements during the zero-flow test in the fall of 1992 have been summarized, the numbers of fish with spaghetti-loop tags counted at the counting windows of the three dams upstream from Ice Harbor Dam, and the numbers of loop-tagged fish captured in the adult trap at Lower Granite Dam. Data from the fish

released with radio transmitters in 1991 and 1992 during the zero-flow test, recaptures in the fisheries, and recaptures at the hatcheries have been completed and are presented in this report.

***Fish counted at the dams.***-Steelhead in the first three groups tagged with spaghetti-loop tags and released for the zero-flow study moved upstream and passed over the three upstream dams with well defined peaks 3-5 d apart (Figure 48). Fish in the fourth and fifth groups moved upstream noticeably slower and fewer fish were counted at the upstream dams compared to the first three groups. Peak numbers of the first group (orange tag) were counted at Lower Monumental Dam 5 d after release, at Little Goose Dam after 9 d, and at Lower Granite Dam after 10 d. Similar timing was observed for the second and third groups released.

At Lower Monumental Dam, steelhead with the loop tags started passing and were recorded by the fish counters 1 or 2 d after the first releases from the first four tag groups (Figure 49). Steelhead in the fifth group were not counted at Lower Monumental Dam because counting was discontinued at the end of October, and fish for the first, second, third and fourth groups were counted for 53, 39, 25, and 11 d, respectively. Despite the unequal number of counting days after release at Lower Monumental Dam for the first four groups of tagged steelhead, the data can be analyzed because most of the fish had passed the dam within 10 d of release (Figure 48). Mean and median days to pass Lower Monumental Dam and the percentage of fish released that were counted was based on the first 11 d of counting after release so the data would not be biased from the unequal periods of counting. The mean days to pass Lower Monumental Dam after release at Charbonneau Campground ranged from 4.5 to 6.9, and the median day of passage ranged from three d for the second group to six d for the fourth group (Table 19).

At Little Goose Dam, fish counters started recording the passage of fish from all four groups 3-4 d after their respective releases (Figure 49). The minimum period of counting for any group at Little Goose Dam was 27 d, so the mean and median days to pass, and the percentage counted at the dam was based on the first 27 d after each release. The mean days to pass Little Goose Dam ranged from 8.4 d for the second group to 12.9 d for the fourth group (Table 19). The median day of passage ranged from day 6 to 11.

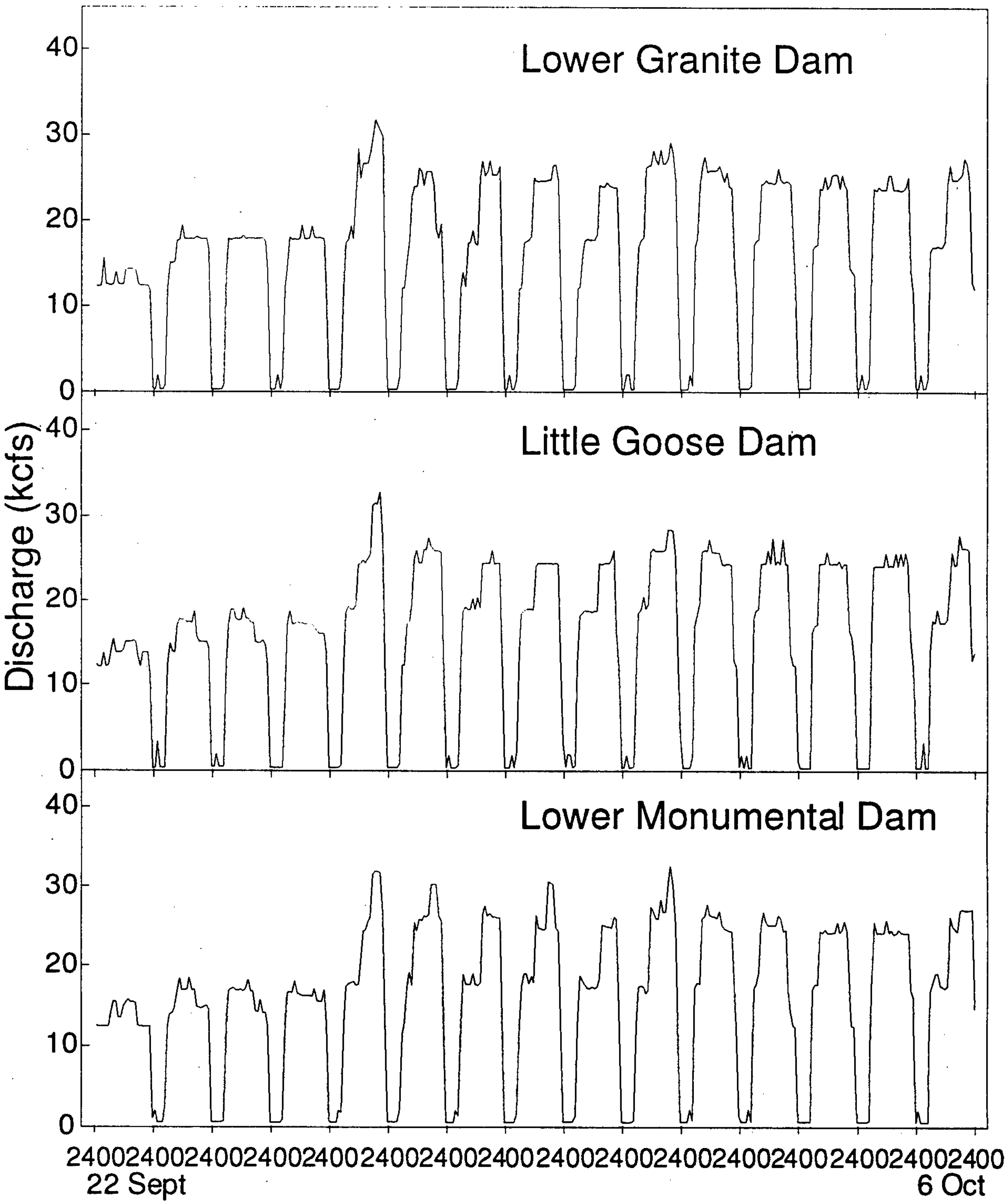



Figure 46. Discharges from the three upper dams in the lower Snake River during the two-week period from 22 September to 6 October 1992 when flows were reduced to near zero from about 2300 to 0600 hr each night.

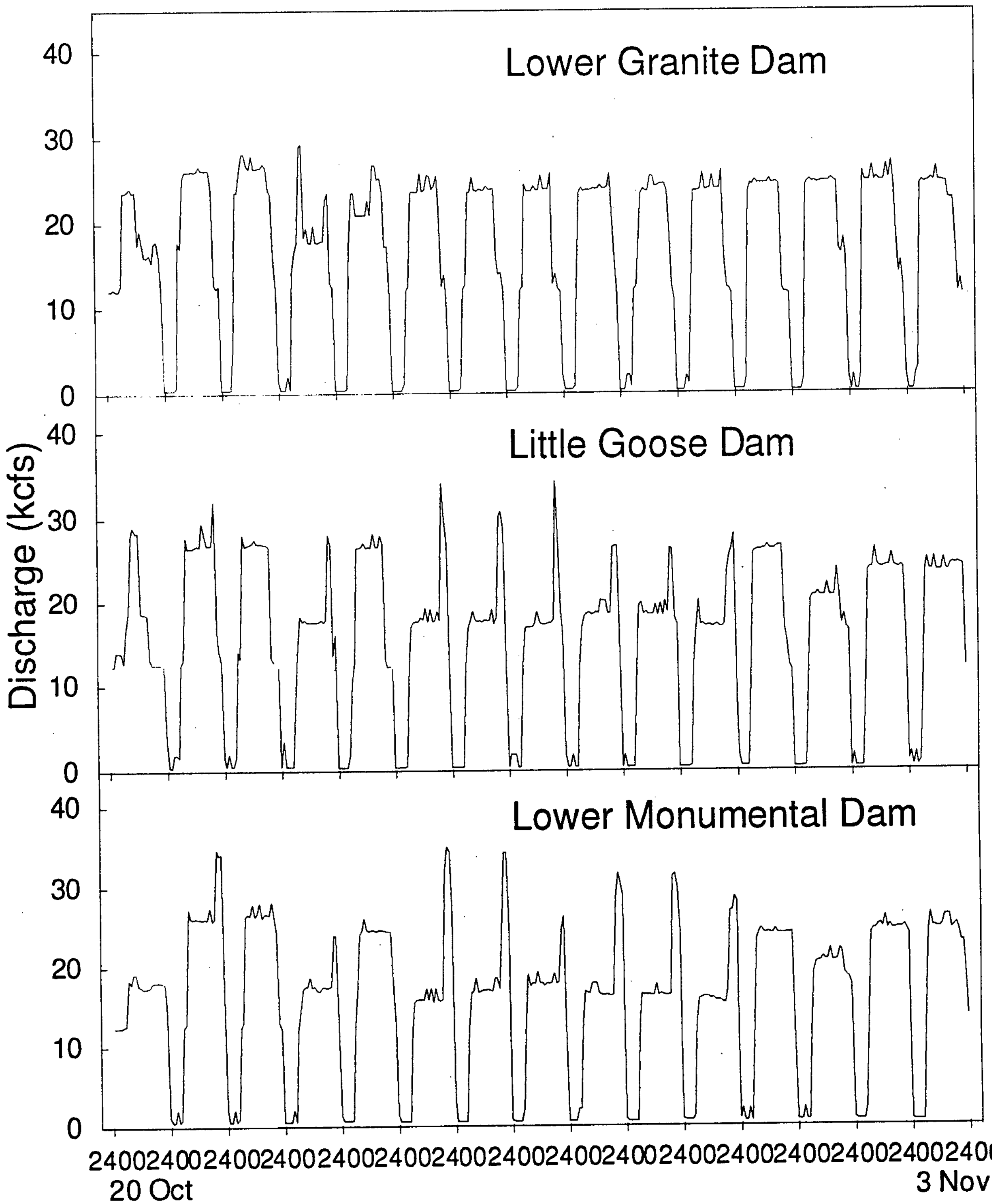



Figure 47. Discharges from the three upper dams in the lower Snake River during the two-week period from 20 October to 3 November 1992 when flows were reduced to near zero from about 2300 to 0600 hr each night.

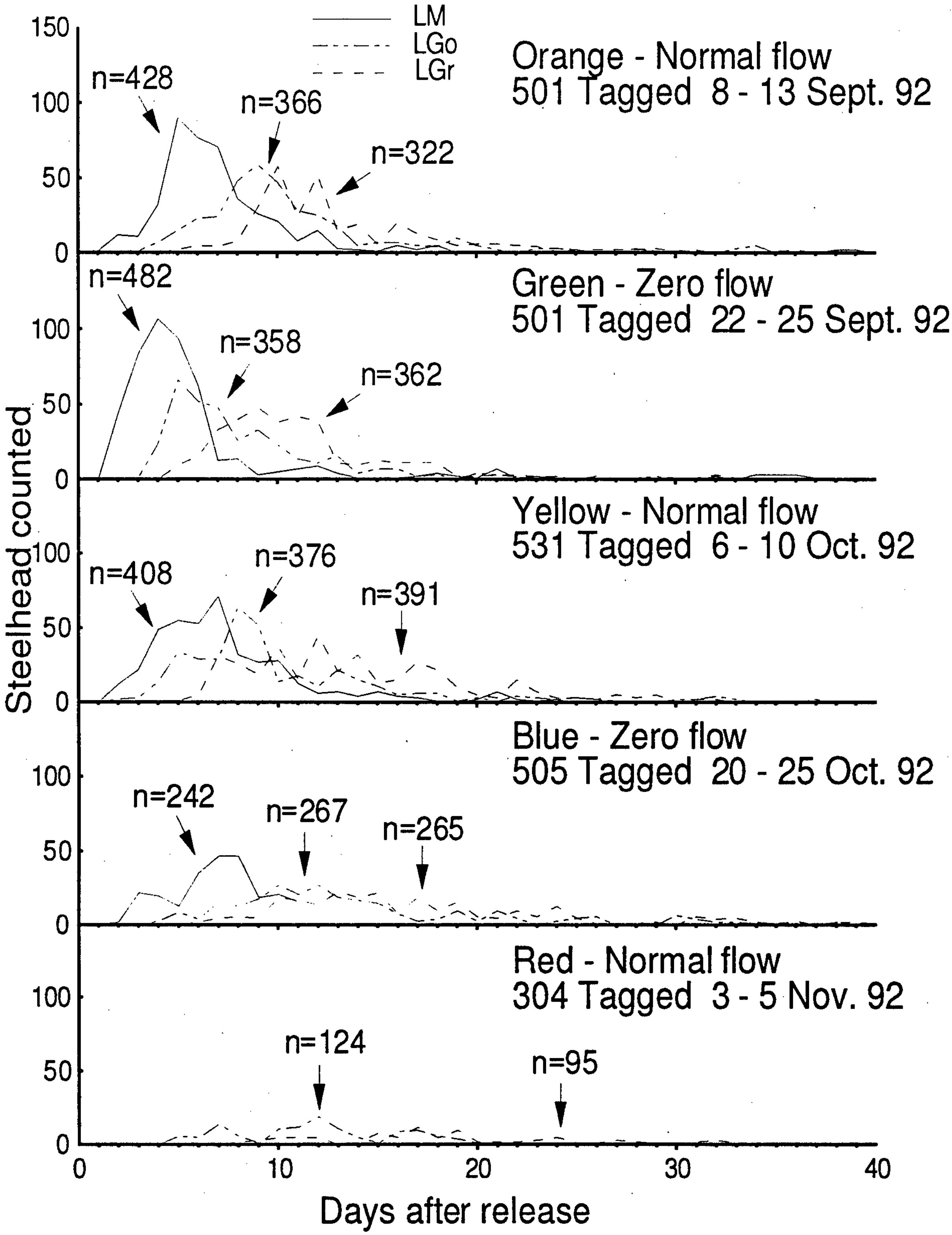



Figure 48. Frequency distribution of steelhead with spaghetti-loop tags that were counted at the three upper dams in the lower Snake River up to 40 d after release to illustrate the timing of each group of fish as they moved up the river in 1992.

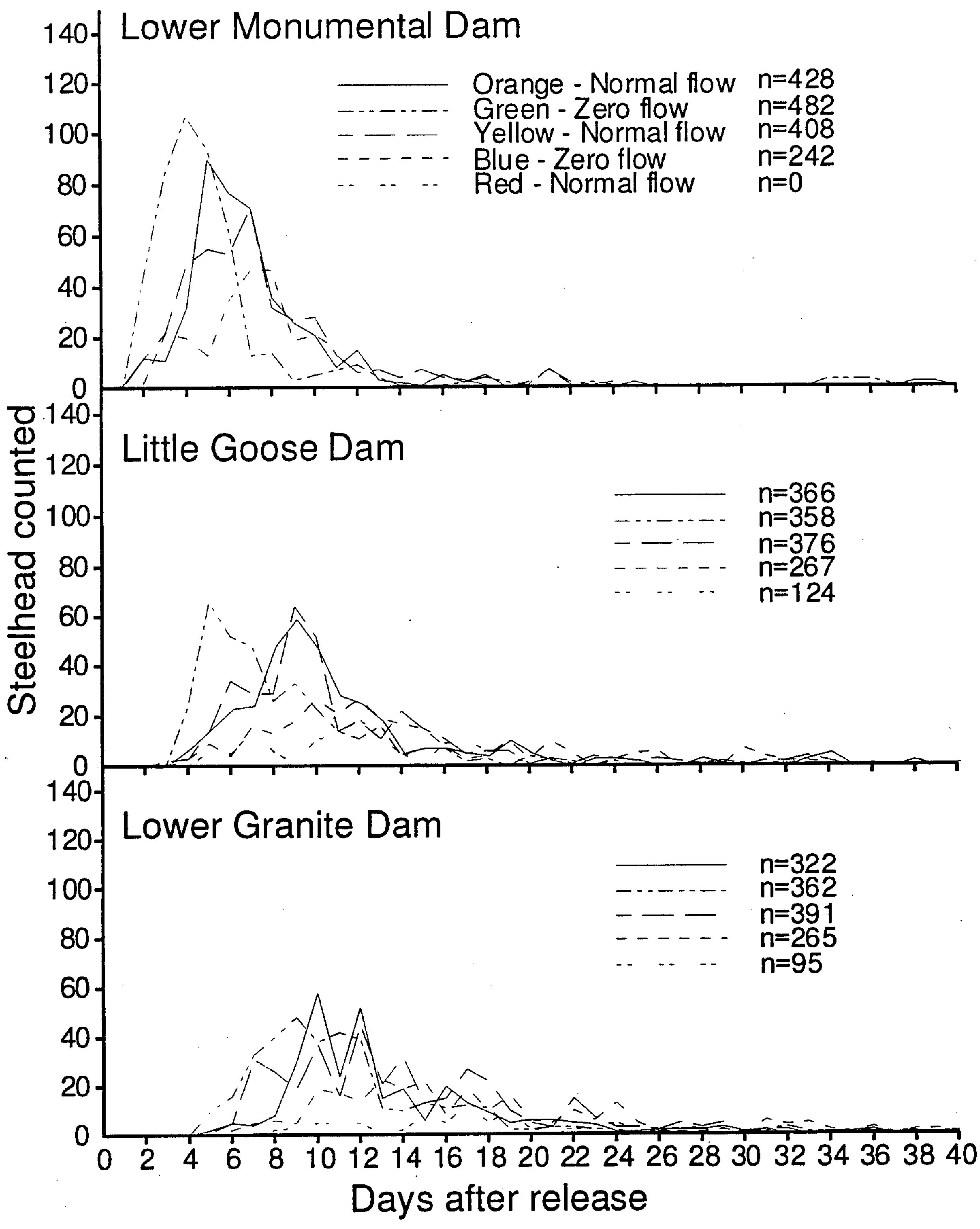



Figure 49. Frequency distribution of steelhead with spaghetti-loop tags that were counted at the three upper Snake River dams to illustrate the timing at each dam following the release of each group of fish in 1992.

Table 19. Mean and median days for steelhead to pass the three Snake River dams upstream from Ice Harbor Dam and percentage of fish released that were counted, based on counts of tagged steelhead passing the counting window for the five groups of spaghetti-loop tagged steelhead released for the zero-flow study in 1992. Estimates based on 11 d of counting after release for Lower Monumental Dam, 27 d of counting at Little Goose Dam, and 42 d at Lower Granite Dam.

| Group number Release dates Tag color | Flow at night | Lower Monumental Dam | | | Little Goose Dam | | | Lower Granite Dam | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean (d) | Median (d) | Percent | Mean (d) | Median (d) | Percent | Mean (d) | Median (d) | Percent |
| Group 1 8-13 Sep Orange | Normal | 6.3 | 5 | 85.4 | 10.4 | 8 | 73.1 | 13.8 | 11 | 64.3 |
| Group 2 22-25 Sep Green | Zero | 4.5 | 3 | 96.2 | 8.4 | 6 | 71.5 | 11.6 | 9 | 72.3 |
| Group 3 6-10 Oct Yellow | Normal | 6.3 | 5 | 76.8 | 10.7 | 9 | 70.8 | 14.3 | 13 | 73.6 |
| Group 4 20-25 Oct Blue | Zero | 6.9 | 6 | 47.9 | 12.9 | 11 | 52.9 | 17.6 | 14 | 52.5 |
| Group 5 3-5 Nov Red | Normal | | | | 12.1 | 11 | 40.8 | 19.3 | 17 | 31.3 |

Spaghetti-tagged steelhead began passing Lower Granite Dam 5 or 6 d after their respective releases (Figure 49). Counting of fish at Lower Granite Dam continued into December and the last group released was counted for 42 d, so estimates of mean and median days to pass and percentages counted were based on the first 42 d after each group was released. Mean days to pass Lower Granite Dam ranged from 11.6 for the second group to 19.3 for the fifth group (Table 19). The median day of passage ranged from day 9 to 17.

The cumulative frequency distributions of fish passing each dam versus days after release illustrate some of the migration differences between the five groups of fish (Figure 50). The cumulative distributions for the first, third and fourth groups counted at Lower Monumental Dam appear similar. The second group (green tags) appears to have migrated slightly faster than the others. At Little Goose Dam, the cumulative passage patterns of groups one and three (orange and yellow tags) are similar, but group two (green tags) appears to have migrated faster and groups four and five (blue and red tags) slower than the other groups.

River temperatures declined steadily during the zero-flow study, as we expected, and may have been more of a factor in migration rates and behavior than other factors. In 1992, the order of periods with zero versus normal flow at night was reversed from 1991 to determine if fish that enter the Snake River when temperatures are beginning to decline migrate at a slower rate than fish migrating two to four weeks later. Tagged fish from the first release group appeared to migrate at a slower rate than fish from the second release group in both 1991 and 1992 regardless of flow at night.

The percentage of the fish released that were counted at the three dams is based on the minimum number of counting days for each dam as described earlier. The number of tagged steelhead from the four groups counted at Lower Monumental Dam amounted to 96.2% of the second group down to 47.9% of the fourth group (Table 19). At Little Goose Dam, the number counted was 73.1% of the first group and declined to 40.8% of the fifth group. At Lower Granite Dam, the counts amounted to 73.6% of the fish released in the third group and declined to 31.3% of the fifth group. The percentages of fish of each group counted have not been corrected for fallback that may have occurred at the dams or for fish destined to enter the Tucannon River or Lyons Ferry Hatchery. In the spring of 1993, some fish from all five groups were counted at Lower Granite Dam, but the last two groups with the blue and red tags were the most numerous.

***Fish recaptured at Lower Granite Dam.***-Recaptures of fish with spaghetti-loop tags at the adult trap at Lower Granite Dam had the same patterns in terms of timing of recaptures as the counts of tagged fish in the fishways. Fish in the first group (orange tags) released at Charbonneau Campground starting on 8 September began showing up at the Lower Granite trap 5 d later on 13 September, with the mode on the 11th d and median on the 13th day after release, and the mean at 13.4 d (Figure 51, Table 20). The peak numbers of recaptures (modes) were 11, 12, 13, 14 and 18 for groups 1 through 5 respectively. The last group was available for recapture for 32 d and so that was the period of trapping used to calculate the median and mean days to recapture for all groups. The median days to recapture at Lower Granite Dam ranged from the 12th for the second group to the 18th for the fifth group. The mean days till recapture at Lower Granite Dam was lowest for the second group (11.5 d) and highest for the fifth group (17.1 d).

The percentage of each group of fish released for the zero-flow test that were recaptured at the Lower Granite adult trap ranged from a high of 67.7% for the second group (green tags) to 39.1% for the fifth group (Table 20). These percentages are for the first 32 d of trapping after release of the respective groups, and they have not been corrected for any fallback that may have occurred at the dams or loss of tags, which was minimal. The percentage recaptured was higher if the first 45 d of trapping was used and Group 5 was dropped out (57.9, 67.7, 69.7, and 57.4% for Groups 1-4, respectively).

The pattern of recaptures of steelhead at the Lower Granite trap was similar in both 1991 and 1992 (Figure 52). The highest percentage recaptured were fish in the second group released in both years, with smaller percentages recaptured from the first and third groups, and considerably fewer from the fourth and fifth groups. Smaller percentages were recaptured in 1992 than in 1991, partly because we used recaptures for the first 32 d following release in 1992 (days after release of group 5 that the trap was operated) versus the first 50 d in 1991. High river temperatures during the earlier part of the run, and declining temperatures during the latter part seem to be major factors in the rates of movement and percentages of fish in each group crossing over Lower Granite Dam in the fall. In both years, we started the zero-flow test when there were enough steelhead crossing over Ice Harbor Dam to fulfill sample size requirements. The first period started on 16 September in 1991 and on 8 September in 1992. Temperatures were cooler in early September of 1992 and the fish entered the Snake River earlier than in 1991. In 1991 the first period was with zero flow at night, and in 1992 the nighttime flow was normal in the

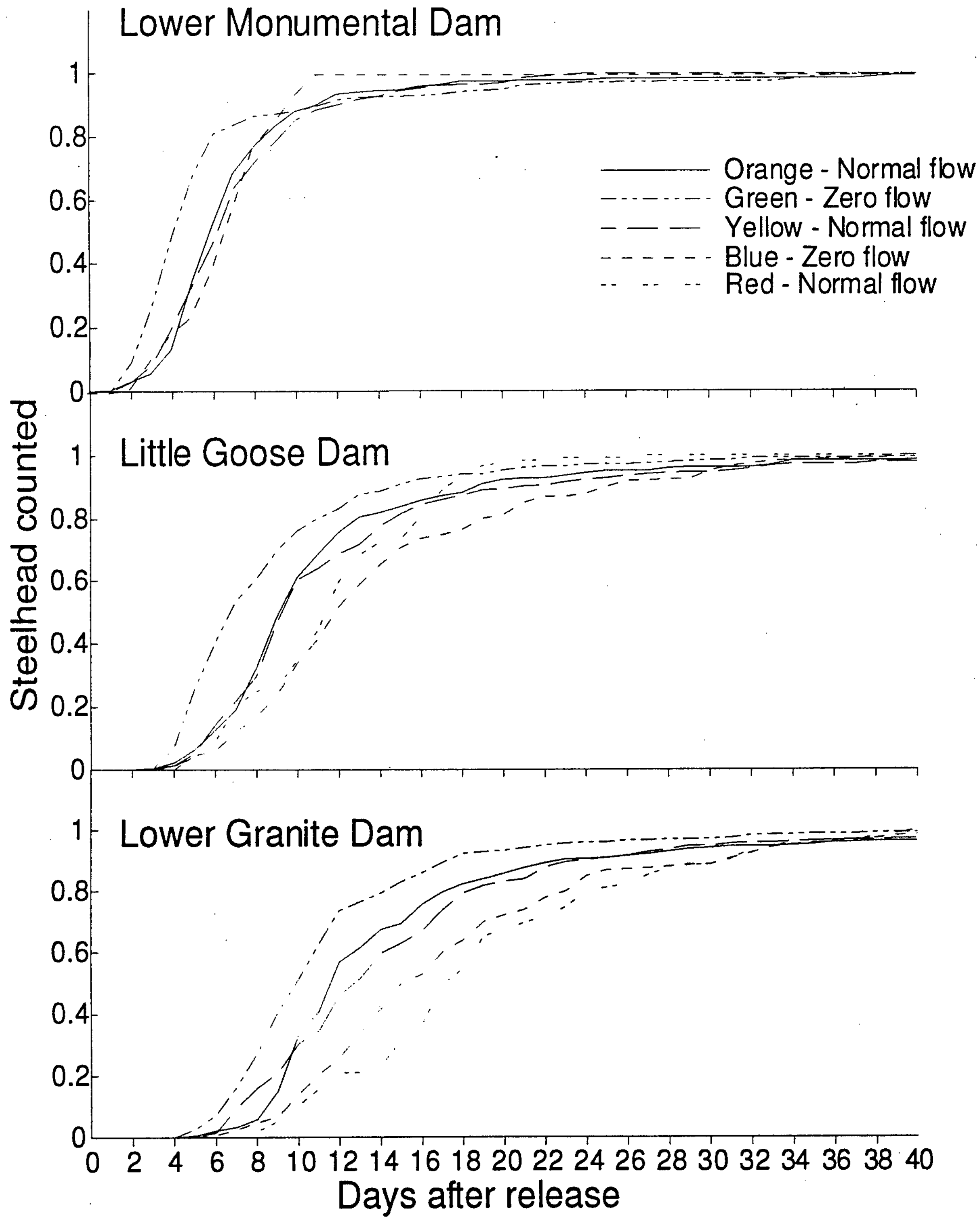



Figure 50. Cumulative frequency distribution of steelhead of each of the five groups tagged with spaghetti-loop tags, counted at the three upper Snake River dams in fall 1992.

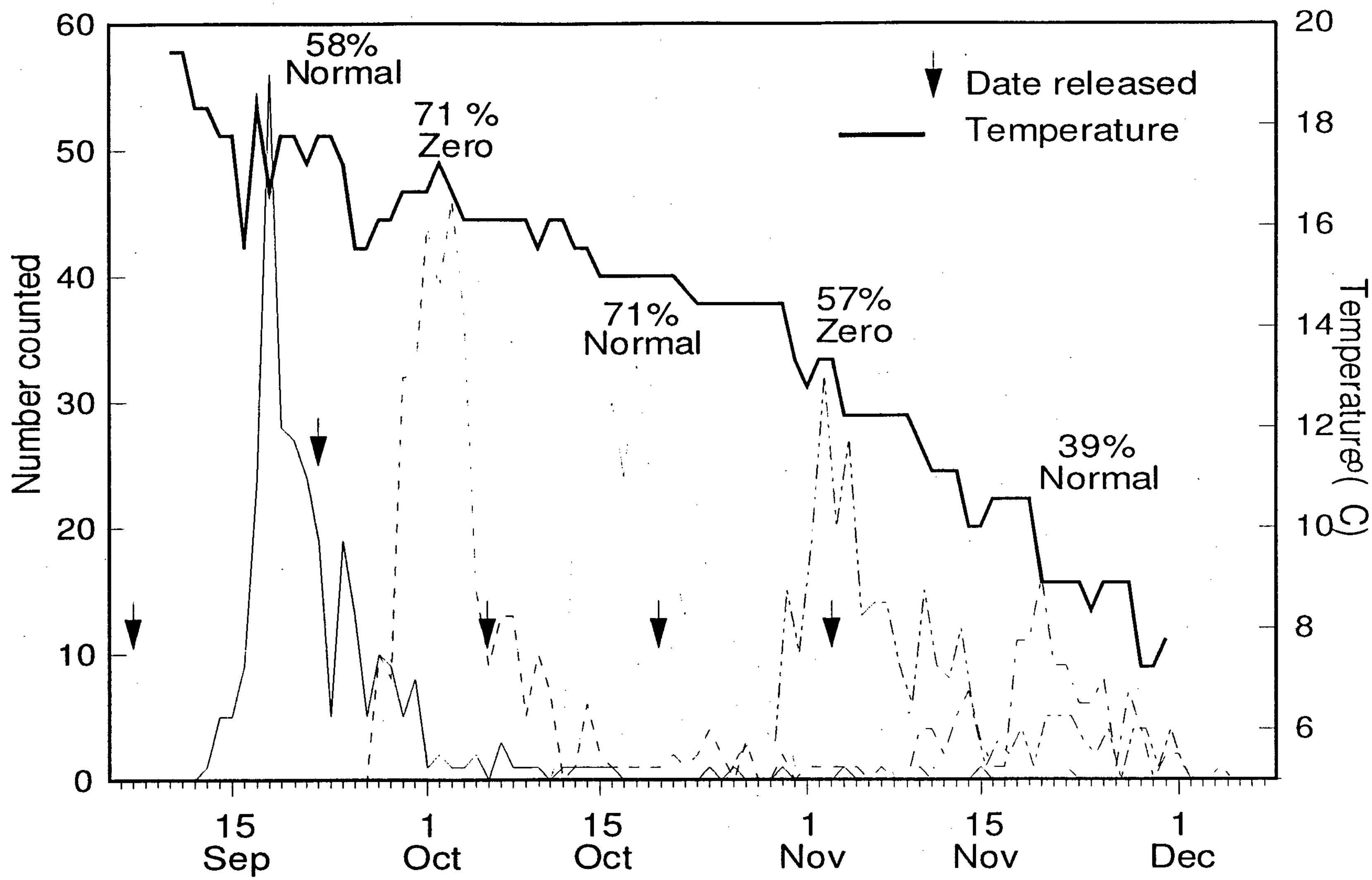



Figure 51. Timing of release and recapture and percent of steelhead adults released with spaghetti tags in each two-week period of normal- or zero-flow at night in the fall of 1992 that were recaptured at the Lower Granite Dam trap through the first part of December, and the temperature of the Snake River.

Table 20. Mode, median, and mean days till recapture of steelhead at the Lower Granite adult trap that were tagged with spaghetti-loop tags and released at Charbonneau Campground during the zero-flow test in 1992. Data used was for the first 32 d after release of each group.

| Group number<br>Release dates<br>Tag color<br>(no. released) | Flow at night | Statistics for recaptures at adult trap (days after release) | | | Percent recaptured |
|---|---|---|---|---|---|
| | | Mode | Median | Mean | |
| Group 1<br>8-13 Sep<br>Orange (501) | Normal | 11 | 13 | 13.4 | 56.7 |
| Group 2<br>22-25 Sep<br>Green (501) | Zero | 12 | 12 | 11.5 | 67.7 |
| Group 3<br>6-10 Oct<br>Yellow (531) | Normal | 13 | 14 | 14.2 | 65.2 |
| Group 4<br>20-25 Oct<br>Blue (505) | Zero | 14 | 16 | 16.6 | 50.7 |
| Group 5<br>3-5 Nov<br>Red (304) | Normal | 18 | 18 | 17.1 | 39.1 |

first period. So far in the testing, we have not found evidence that the migration of steelhead through the lower Snake River has been influenced by the zero-flow at night conditions created in the three lower reservoirs.

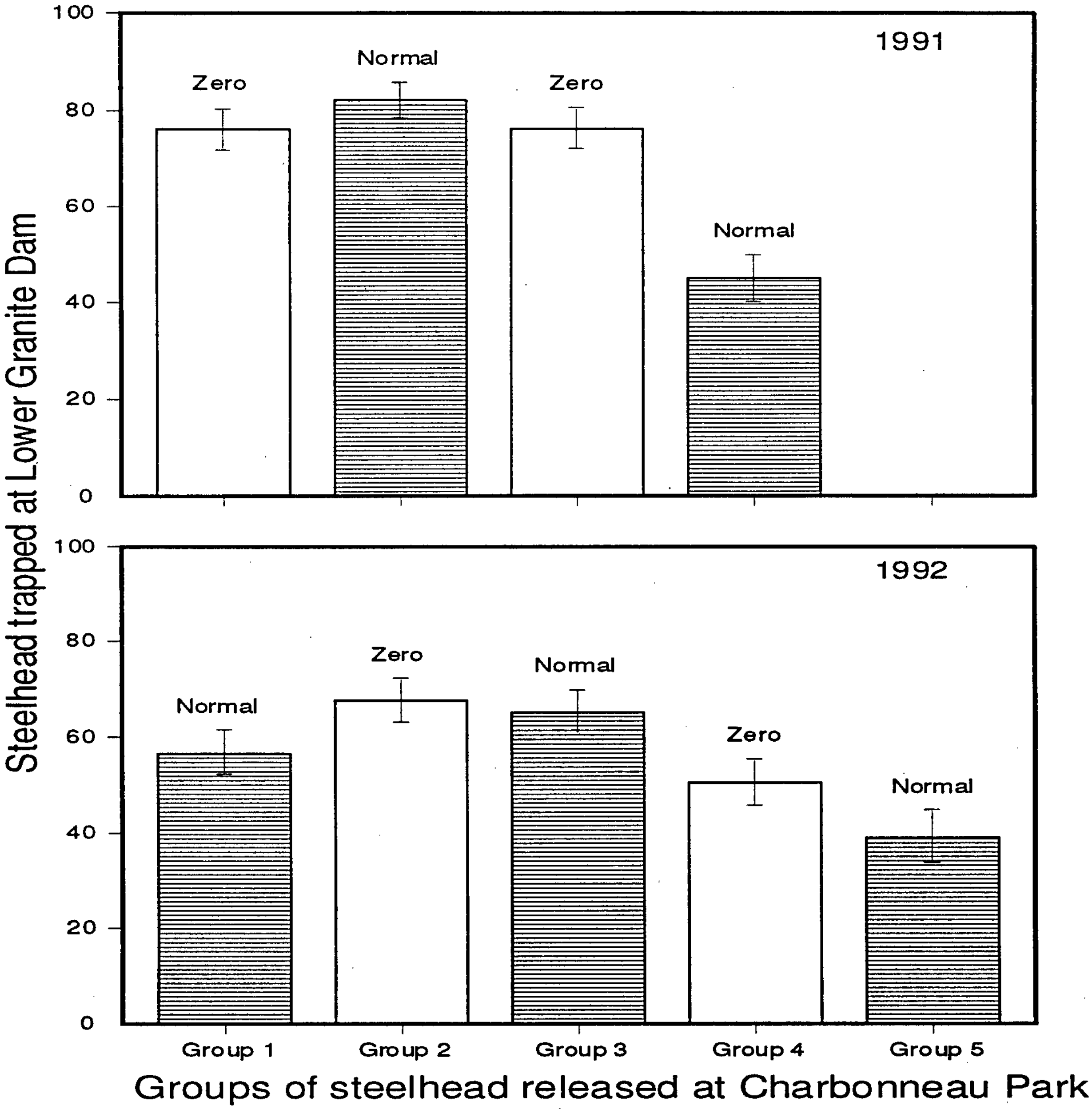



Figure 52. Mean percent recaptures (with 95% confidence intervals) at the Lower Granite trap of adult steelhead released with spaghetti-loop tags upstream from Ice Harbor Dam during the falls of 1991 and 1992. Each group represents fish released at the start of a two-week period and recaptured for 50 d in 1991 and 32 d in 1992.

### *Methods - Steelhead with Transmitters*

During September, October, and November of 1991 and 1992, more than 500 steelhead were outfitted with radio transmitters and released each year at Charbonneau and Hood Park campgrounds. In addition to providing general information on steelhead movements within the Snake River basin, the movements of these fish were analyzed for the zero-flow portion of this study.

The analysis of movements of fish with transmitters during the zero-flow test was conducted on a reservoir by reservoir basis. In order for an individual fish to be included in the analysis of fish movements through a reservoir under a particular flow regime, the fish had to be exposed to only one flow regime for the entire period of time that it was in the reservoir. Fish that entered a reservoir under one flow regime had to exit the reservoir prior to the beginning of the next flow regime in order to be included in the analysis of movements through that reservoir.

Migration times through reservoirs for fish with transmitters were calculated by subtracting the date and time for the last record for a fish at the top of a fish ladder at one dam from the date and time for the first record for that fish at the downstream receiver site at the next dam upriver. The distance between the receiver sites was then divided by the migration time to give a migration rate for an individual fish through the reservoir.

### *Results - Steelhead with Transmitters*

**Fish with transmitters in 1991.**-In the fall of 1991, 524 steelhead were outfitted with transmitters, and 313 of those fish were used in the zero-flow test for one or more reservoirs. The other 211 failed meet the criteria of being exposed to only one flow regime during their passage through any one reservoir.

Steelhead with transmitters that were analyzed for the zero-flow test migrated through the lower Snake River reservoirs at rates ranging from a low of 4.2 km/d to a maximum of 74.9 km/d. On average, during the zero-flow test, fish with transmitters migrated though the lower Snake River reservoirs at about 26.1 km/d. While there were differences in migration rates observed during the two flow regimes (Figure 53) and in different reservoirs (Figure 54), the differences do not appear to be related to zero or normal nighttime flows.

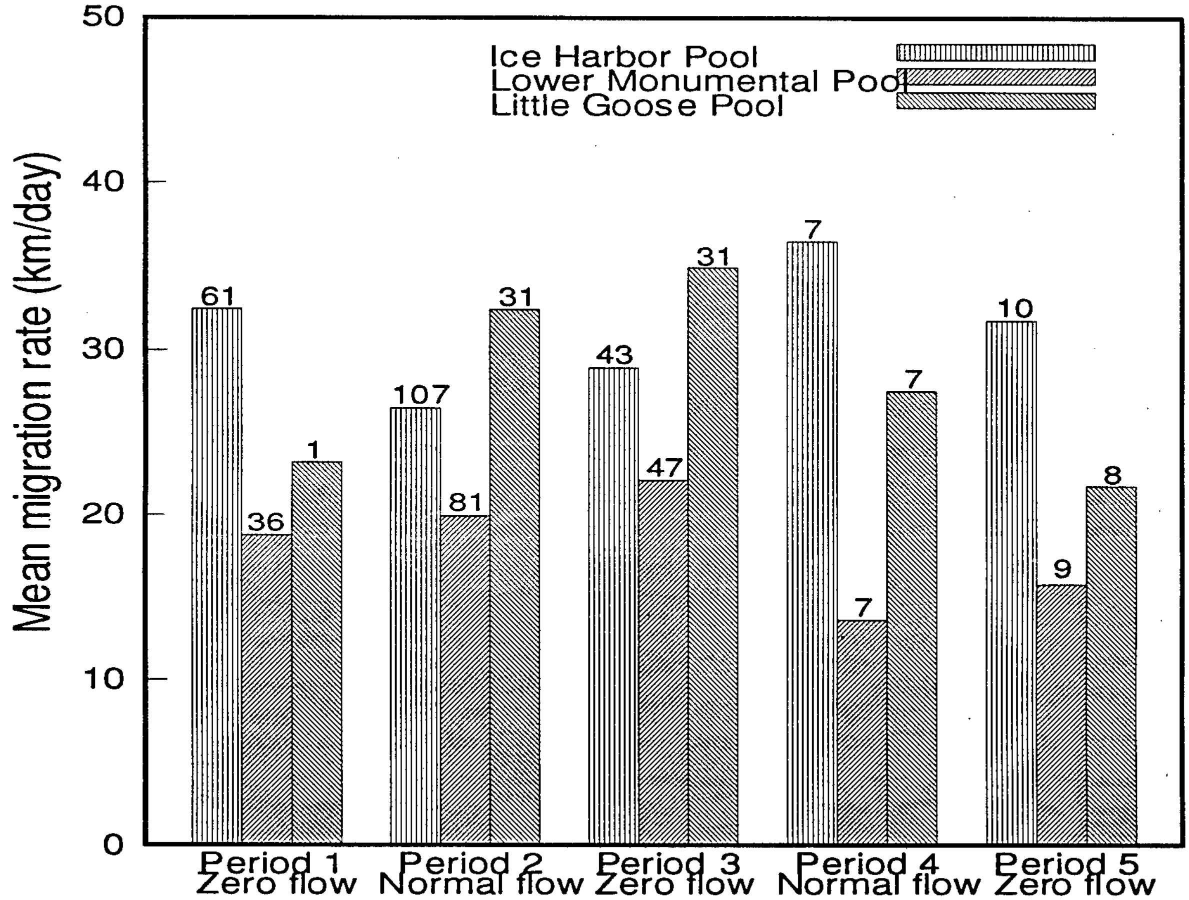



Figure 53. Mean migration rates of steelhead outfitted with transmitters in 1991 during periods of zero and normal nighttime flow in three of the lower Snake River reservoirs. Numbers on top of bars are the number of fish monitored.

Steelhead migrated slower through Lower Monumental Reservoir than the other two reservoirs during all flow conditions. Steelhead with transmitters that migrated through the Little Goose pool during test periods 2 and 3 migrated at faster rates than fish migrating during the other periods.

***Fish with transmitters in 1992.***-In the fall of 1992, 515 steelhead were tagged with transmitters. Of those, 382 individuals were used in the zero-flow test for one or more reservoirs. The other 133 fish failed meet the criteria of being exposed to only one flow regime during their passage through any one reservoir.

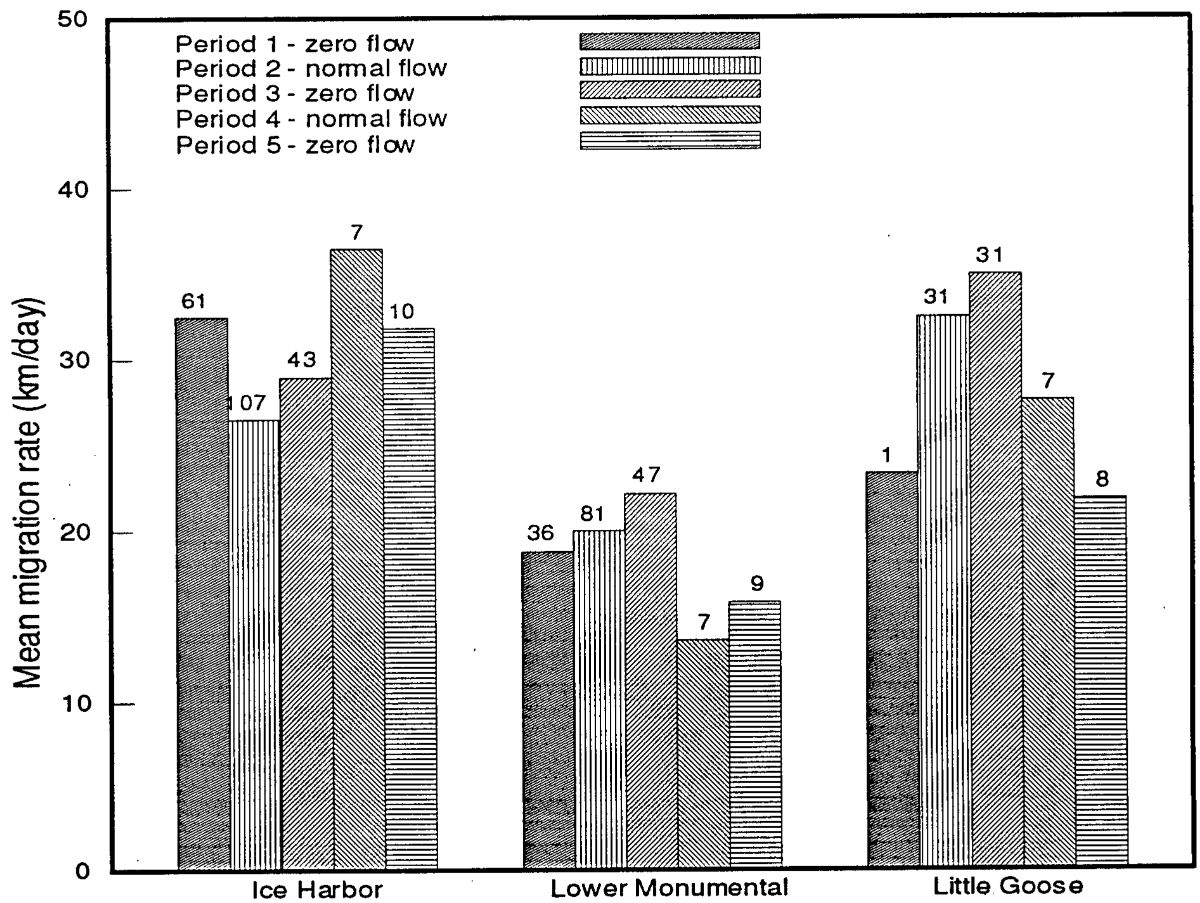



Figure 54. Mean migration rates of steelhead outfitted with transmitters as they migrated through three of the lower Snake River reservoirs during each period of the 1991 zero-flow test. Numbers on top of bars are the number of fish monitored.

Steelhead with transmitters that were analyzed for the zero-flow study in 1992 migrated through the lower Snake River reservoirs at rates ranging from a low of 3.8 km/d to a maximum of 105.8 km/d. On average, during the zero-flow test, fish with transmitters migrated though the lower Snake River reservoirs at about 31.0 km/d. As occurred in 1991, there were differences in migration rates for steelhead observed during different flow regimes (Figure 55) and in different reservoirs (Figure 56). Steelhead with transmitters migrated through Little Goose Reservoir at a faster rate than in the two downstream reservoirs during all five test periods. The pattern of most rapid migration during the second and third periods and lesser rates during periods 1 and 4 for the steelhead with spaghetti-loop tags (Figure 52) was not as obvious for fish with transmitters (Figure 56).

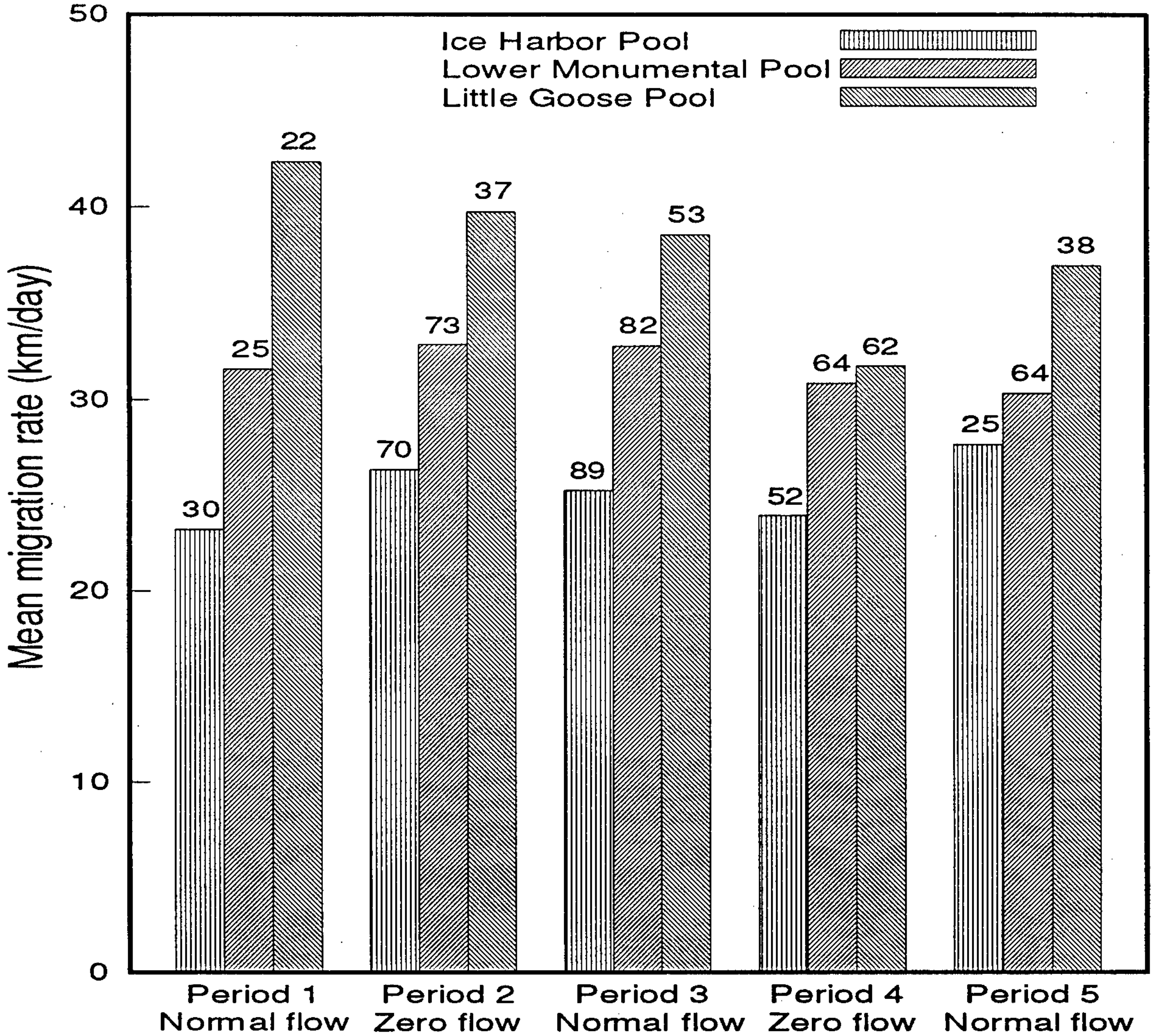



Figure 55. Mean migration rates of steelhead outfitted with transmitters in 1992 during periods of zero and normal nighttime flow in three of the lower Snake River reservoirs. Numbers on top of bars are number of fish monitored.

Migration rates of steelhead with transmitters through all three reservoirs influenced by the zero or normal flows at night did not differ significantly in 1991 or 1992 (Figure 57), and do not appear to be related to the flows at night. The decline in water temperature during the fall appears to have more influence on migration rates than a reduction of flows at night to near zero.

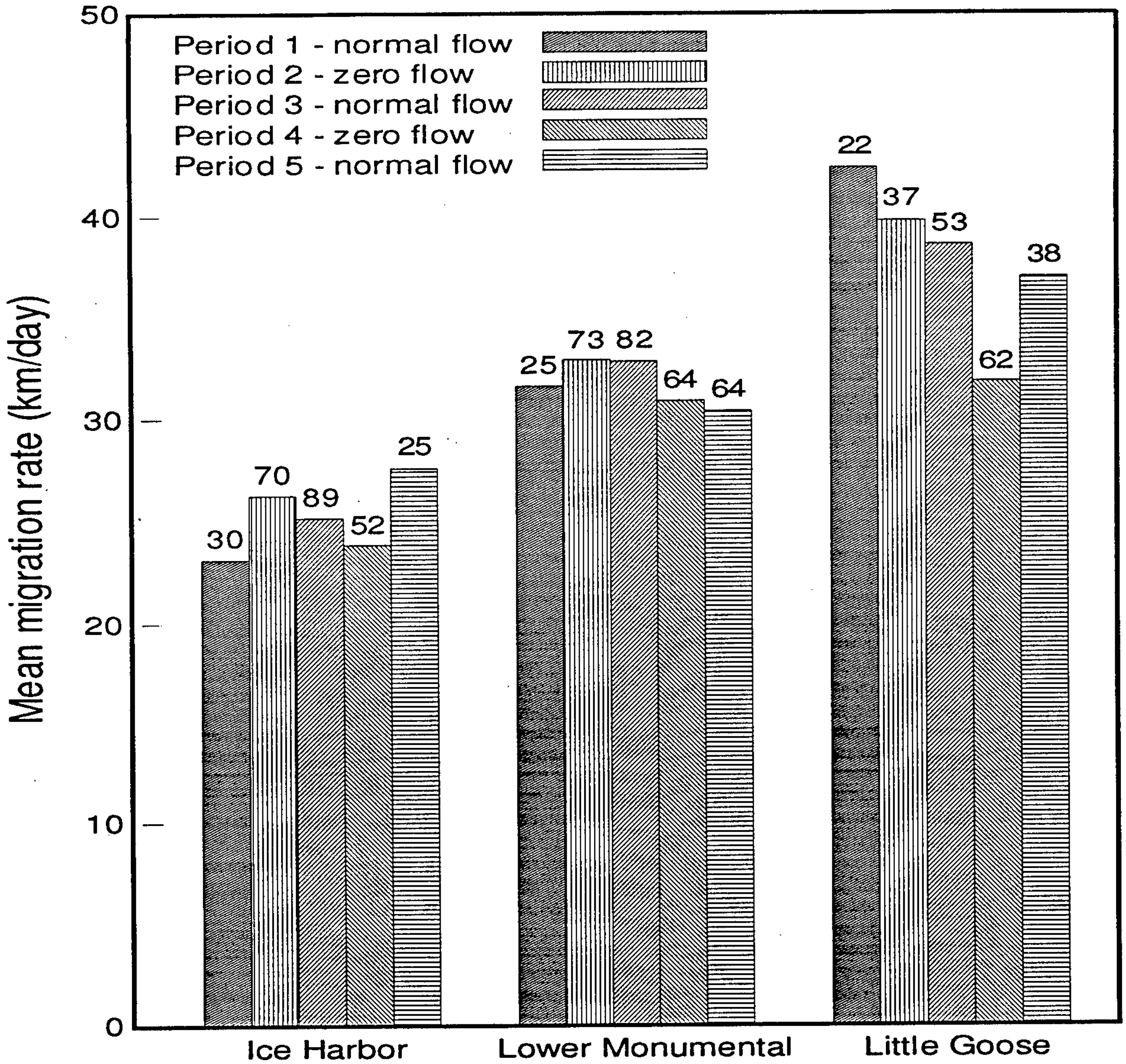



Figure 56. Mean migration rates of steelhead outfitted with transmitters as they migrated through three of the lower Snake River reservoirs during each period of the 1992 zero-flow test. Numbers on top of bars are number of fish monitored.

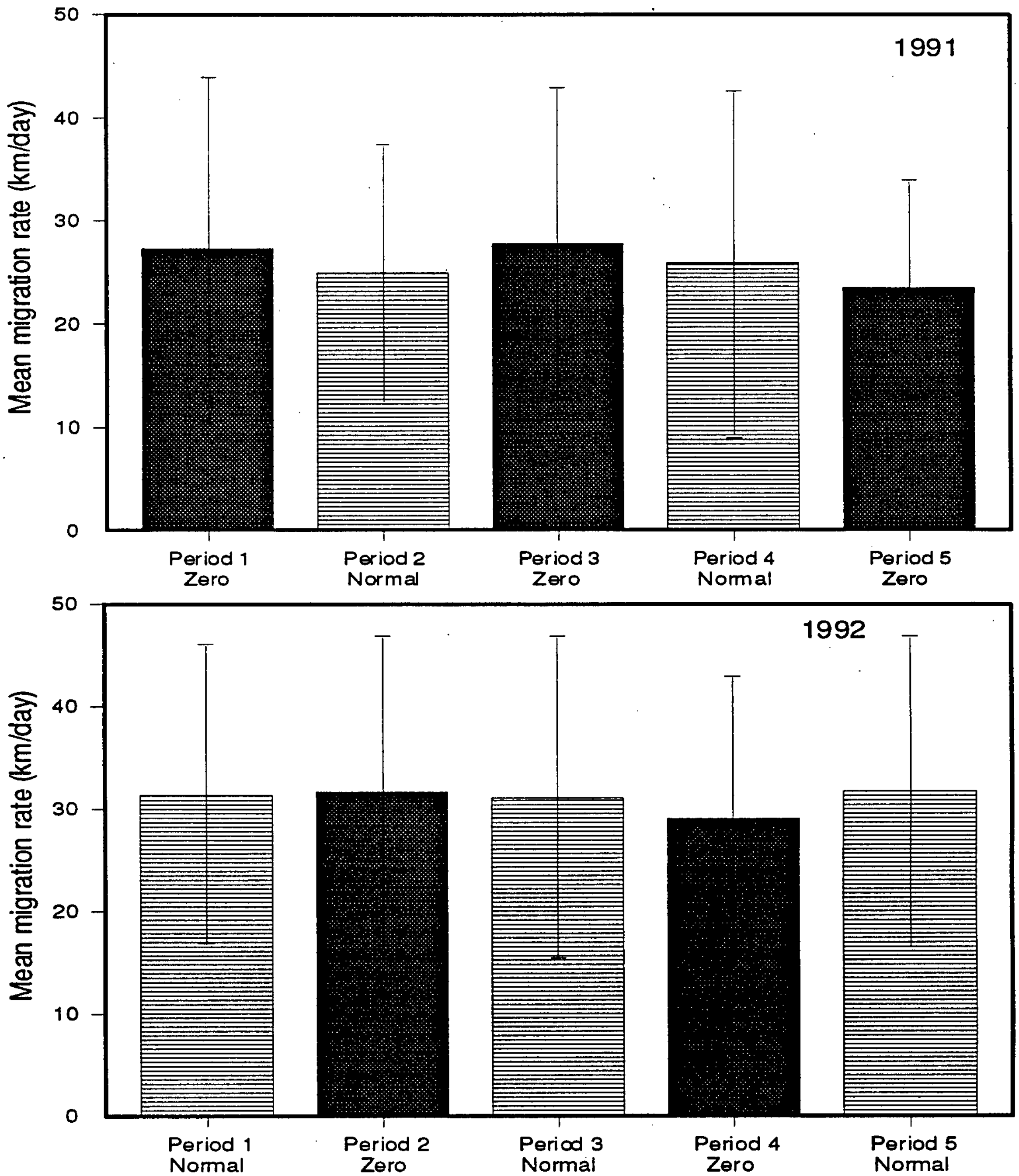



Figure 57. Mean migration rates of steelhead with transmitters through the three reservoirs (data combined) for the two-week periods influenced by the zero and normal flows at night in 1991 and 1992. The vertical lines are the 95% confidence intervals.

## Water Temperatures at the Dams

During 1992, as in 1991, electronic temperature recorders were installed and maintained at the top of a fishway, at the lower end of the fishway (upstream from the supplemental flow inlets), and in the tailrace at each of the Snake River dams during the summer and fall. Water temperatures reached a peak of 23-25°C in mid August in the lower Snake River (Figures 58-59). The discharge from the turbines (tailrace) was often 1-3°C cooler than water at the top of the fishway, or at the lower end upstream from the supplemental water inlets. The water warmed as it moved from the top to the bottom of the Ice Harbor south-shore fishway during the hot sunny days of summer and fall.

The releases of cool water (about 45°F) from Dworshak Dam in early June, 5-18 July, and 10-20 September of 1992 had a measurable effects on the tailrace temperatures at Lower Granite Dam in late June, early July and mid September (Figure 59). Temperatures in the Little Goose Dam tailrace appeared to be slightly reduced by the cool-water releases during the same periods, but reductions in temperatures of water discharged from Lower Monumental and Ice Harbor dams that could be attributed to the cool-water releases were not obvious (Figure 58). Periods of cooler-than-normal weather in early July and late August-early September of 1992 (Karr 1992) that cooled the inflowing rivers at Lewiston added some uncertainty to the effects of the releases of cool water on cooling the temperatures in the lower Snake River.

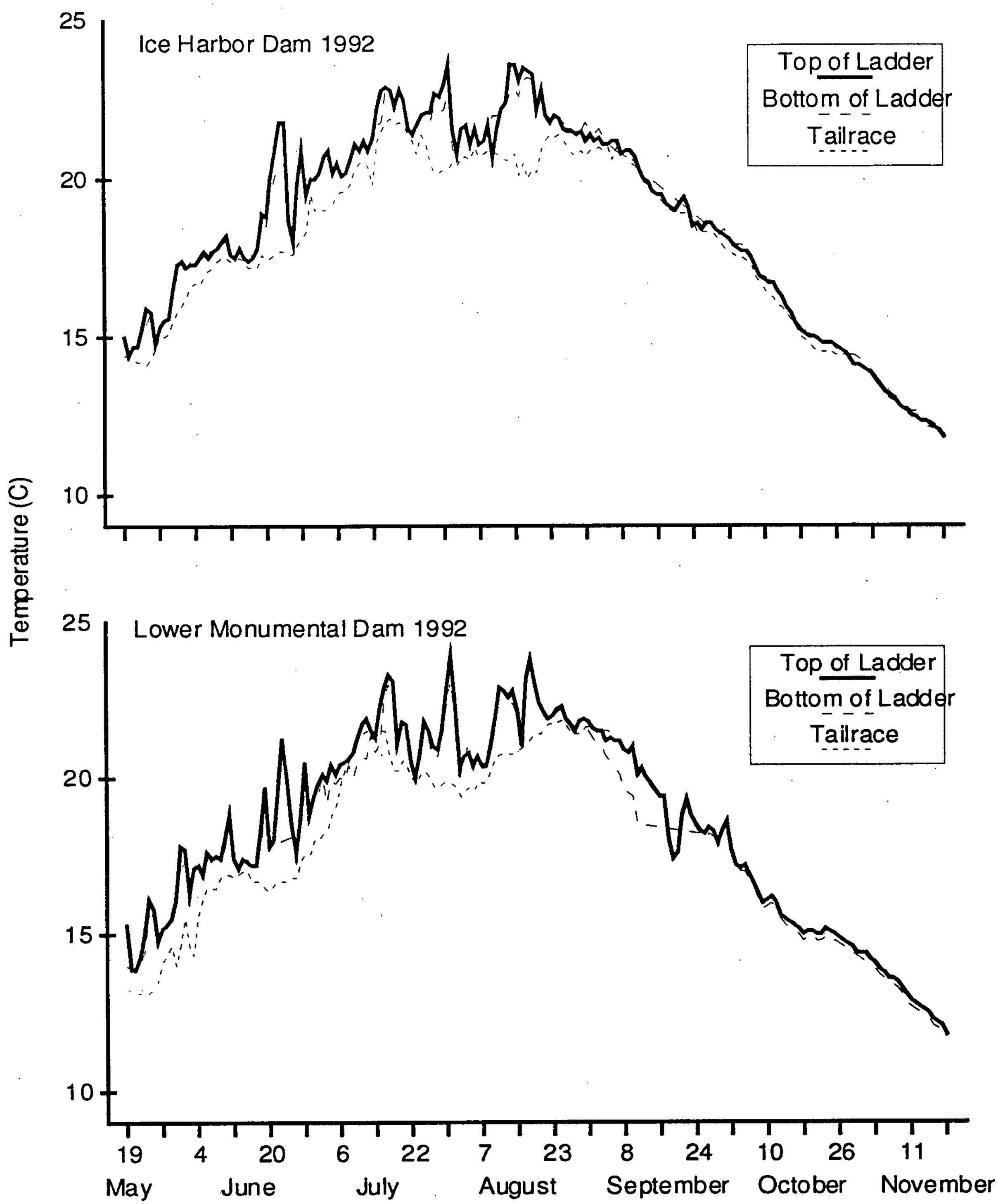



Figure 58. Water temperatures at Ice Harbor and Lower Monumental dams in 1992 at the top of the ladders, near the bottom of the ladders upstream from the supplemental flow inlets, and in the tailrace downstream from the dams.

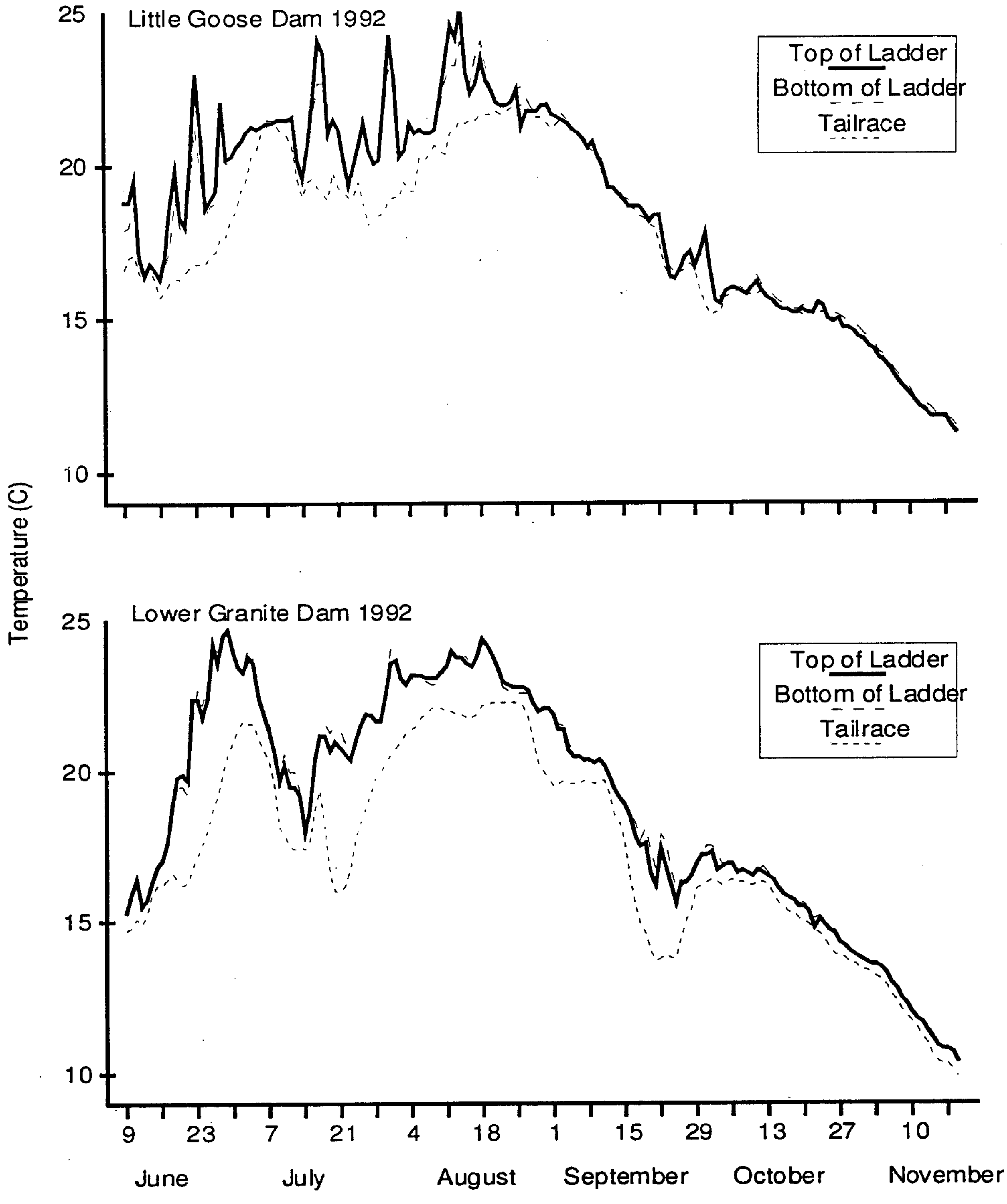



Figure 59. Water temperatures at Little Goose and Lower Granite dams in 1992 at the top of the ladders, near the bottom of the ladders upstream from the supplemental flow inlets, and in the tailrace downstream from the dams.

## Discussion

Conditions for upstream migration of adult spring and summer chinook salmon in the lower Snake River were favorable in 1992 because of the low flows, lack of spill, and low turbidities during most of the spring and early summer. The migration rates observed in 1991 and 1992 were near the high end of the range observed in past studies (Bjornn and Peery 1992) and probably represent the rates that can be expected under conditions that are favorable for upstream migrants. In years with higher spring runoffs, spill at the dams, and more turbid water, the fish may not pass through the lower Snake River as quickly as in 1991 and 1992. In 1981 for example, Turner et al. (1983) reported that chinook salmon took nearly 8 d on average to pass Lower Granite Dam when spill exceeded 25 kcfs versus only 2 d when there was less spill. The mean time for chinook salmon to pass Lower Granite Dam in 1991 was 3.1 d, and 2.3 d in 1992 and there was no spill in either year.

The median times of 1.2 and 1.3 d for spring and summer chinook salmon to pass Ice Harbor and Lower Granite dams, respectively, in 1992 were 3 to 6 times longer than passage times at Lower Monumental and Little Goose dams, but were still relatively rapid. Operation of fish traps in the ladders of Ice Harbor and Lower Granite dams and forcing the tagged fish to pass Ice Harbor Dam a second time may have contributed to the longer passage times at those two dams. The median passage time at Ice Harbor Dam in 1992 was reduced to 1.2 d from 5.4 d in 1991 by removing the trap box from the water when trapping was finished each day, thereby allowing the fish to migrate past the trapping site in the ladder through the entire water column instead of under the trap.

Migration rates of chinook salmon through the Snake River reservoirs (about 25 to 63 km/d) and in free-flowing rivers upstream from the dams (12-38 km/d) in 1991 and 1992 were similar to those observed in prior years (Turner et al. 1983, 1984; Oregon Fish Commission 1960). We will attempt to correlate migration rates of individual fish with turbidity in the reservoirs and rivers where we can obtain such information.

Success of passage of spring and summer chinook salmon with transmitters from the tailrace at Ice Harbor Dam to the receivers upstream from the Lower Granite Reservoir was 79% in 1992. Passage from the top of Ice Harbor to the top of Lower Granite dams was 87% in 1991 and 85% in 1992, rates similar to that observed from an analysis of counts of all adults at the two dams from 1975 to 1989 (Bjornn 1990), and in 1992 (83% passage). Survival from the Ice Harbor Dam tailrace to the spawning grounds or

hatcheries was estimated at 63% in 1992 versus 54% in 1991. These estimates are maximum survivals because fish that died before spawning in some streams could not be estimated. In a separate effort, Bjornn (1990) estimated that 45 to 55% of the wild chinook salmon passing Ice Harbor Dam survived to spawn during the 1962 to 1988 period.

Based on the time of capture at Ice Harbor Dam, we were able to use the fish with transmitters to increase the information available on the distribution of spring versus summer chinook salmon in the Snake River basin. The distinction between spring and summer chinook salmon begins with their time of entry into the Columbia River and passage over Bonneville Dam. The separation in timing usually continues as the fish migrate up the river, especially in years like 1991 and 1992 with relatively clear flows. In 1991, there was a nadir in the counts of chinook salmon at Ice Harbor Dam in late May that coincided with a pulse of turbid water that passed through the system. In 1992, there was no pulse of turbid water, but there was a nadir in the counts about the 20th to 25th of May. We believe the fish we tagged and released in April and the first three weeks in May were mostly spring chinook salmon and those tagged and released in late May, June, and July were mostly summer chinook salmon. But, keep in mind when looking at the distribution data that early migrating summer chinook salmon may have reached Ice Harbor Dam by mid May, and that delayed spring chinook salmon may not have made it to Ice Harbor Dam until early June. The distribution of salmon in both 1991 and 1992 varied by drainage and hatchery with some having entirely spring or summer chinook salmon and some areas a mixture of both. As additional years of data are added, we will have a clearer understanding of the fish that make up the stocks in each spawning area and hatchery.

In 1992, the distribution of spring and summer chinook salmon with transmitters into the major Snake River tributaries differed some from 1991, with 4% into the Tucannon River (none in 1991), 15% into the Clearwater (25% in 1991), 2% into the Snake River proper upstream from Lewiston (none in 1991), 10% into the Grande Ronde (9% in 1991), 5% into the Imnaha (4% in 1991), and 63% into the Salmon (62% in 1991) river drainages. The distribution probably reflects the amount of natural and hatchery production in each drainage.

In 1991, 734 steelhead with transmitters and 1,976 with spaghetti-loop and jaw tags were released near Ice Harbor Dam. A complete accounting of the distribution of those tagged steelhead that were recaptured, some of which were alive in the rivers through the spring of 1992, and for which reporting of recaptures by anglers and agency personnel

was not complete until fall of 1992, is presented in this report. Eighty-two percent of the tagged steelhead moved upstream over the lower Snake River dams and were recaptured at the Lower Granite adult trap, mostly in the fall of 1991. Twenty-seven percent of the fish were reported as being caught in fisheries (some fish were released), and 5% were recaptured at hatcheries. The percentage of fish caught by anglers is a minimum rate because most of the reports we received were voluntary.

Only 18% of the steelhead released with transmitters in July of 1991 at Hood Park were recaptured at the Lower Granite trap, compared to 55% of those released in fall at the same location, and 74% of those released upstream from Ice Harbor Dam at Charbonneau Campground. In 1992, we again released steelhead with transmitters upstream from Ice Harbor Dam as well as downstream at Hood Park to see if there were differences in migrations caused by release location along with monitoring the passage of fish past the dams and through the reservoirs. Nearly equal percentages of steelhead released in July at Hood Park (37%) and at Charbonneau (36%) campgrounds were recaptured at the Lower Granite adult trap. Steelhead that were released in the fall downstream and upstream from Ice Harbor Dam were recaptured at different rates (51% and 63%, respectively) at the Lower Granite trap. In both 1991 and 1992 a lesser proportion of the fish trapped at Ice Harbor Dam and released downstream at Hood Park than those released upstream from the dam were recaptured at the Lower Granite trap.

Migration rates of steelhead released with transmitters in 1992 were similar to those in 1991, with fish released in July at Hood Park taking about four times longer to return to the tailrace of Ice Harbor Dam than fish released in the fall. Passage at the dams ranged from 1.0 to 6.8 d on average (medians 0.4 to 2.6 d) for steelhead that migrated through the lower Snake River in the fall of 1992. Passage rates for fall released steelhead migrating through the reservoirs in the fall ranged from about 13 to 27 km/d, based on mean days to pass (16 to 36 km/d based on median days). Migration rates in the free-flowing rivers upstream from Lower Granite Reservoir ranged from about 1 to 14 km/d.

Entrance use and passage through the fishway at Lower Granite Dam by steelhead (356) with transmitters was monitored in the fall of 1992 with newly developed receivers and underwater antennas. Median passage times from the tailrace receiver to first approach at an entrance to the fishway, to entry into the fishway, and passage over the dam were 0.14, 0.23, and 1.13 d, respectively. Steelhead first approached the dam and fishway entrances primarily along the southern half of the powerhouse and at the north powerhouse-3 entrance. A majority of the first and repeated entries into the fishway were

at three entrances, south shore-2, north powerhouse-3, and north shore. Those three entrances also had the highest net entry rates. More fish left the fishway than entered at south shore-1, and north powerhouse-1 and -2 entrances. Steelhead moving downstream in the collection channel along the face of the powerhouse (and several did so) were more likely to exit the fishway via the north powerhouse-1 and -2 entrances because of the fishway fence installed in the channel opposite those two entrances. The fence was designed to reduce fallout at the entrances by fish that were migrating upstream in the fishway.

In a test to evaluate the effectiveness of the three north powerhouse entrances, entrance 3 that faces into the spillway stilling basin had more entries and less exits by steelhead with transmitters in 1992 than either of the other two entrances. When possible, the north powerhouse-3 entrance should be used alone or in combination with one of the other two entrances.

The results from two years of tests to assess the effects of reducing discharge from the three upper dams to near zero at night during the fall on the migration of steelhead have been consistent from year to year and we do not see any clear evidence that flows at night affect fish movements. In 1991, the first of four two-week test periods began in mid September when river temperatures had declined and adequate numbers of steelhead were moving into the Snake River. The first period was a zero flow period followed by one with normal flow, then one with zero flow, and finally the last one with normal flow. In general, migration rates and the percentage counted or recaptured at the upstream dams was highest for the steelhead released at the start of the second period with normal flow at night. Steelhead released in the first and third periods with zero flow at night migrated at similar rates that were almost as fast as the fish in the second period. Steelhead in the fourth period migrated much slower than fish in the earlier periods, despite having normal flow at night. A similar pattern of movement occurred in 1992 with five groups of steelhead released starting earlier in September and the order of zero and normal flow alternated from than in 1991. Although the some of the differences in migration rates and proportions moving upstream during the two-week periods were significant, we doubt the differences are a result of flow at night. River temperatures were declining throughout the duration of the test and may have been the major factor affecting migration rates. We suspect that during the first two-week period temperatures had declined enough that fish began migrating up the river, but were still too high for maximum migration rates. During the middle periods, temperatures were ideal for rapid upstream movement, and by the fourth

periods, temperatures and time of season induced some steelhead to begin their overwintering behavior of holding somewhere in the lower Snake River. Additional tests will help clarify the role of temperature versus flow at night in migration rates and passage through the lower Snake River for steelhead.

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# EVALUATION OF PASSAGE OF ADULT SALMON AND STEELHEAD AT LOWER GRANITE DAM AND OF ELECTRONIC TUNNEL AND UNDERWATER VIDEO TECHNOLOGIES AS PASSAGE EVALUATION METHODS

Annual Progress Report

March 1992 - February 1993

by

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for

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Walla Walla District

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**ABSTRACT**

The study in 1992 concluded a second year of effort by Oregon Department of Fish and Wildlife in evaluating adult salmonid passage at dams in the lower Snake River. We also evaluated two technologies, electronic tunnels and underwater video cameras, for their effectiveness in monitoring passage at fishway entrances. Work was entirely performed at Lower Granite Dam in 1992 during the spring, summer, and fall periods. To evaluate passage at entrances, we used electronic tunnels in the spring and underwater video cameras in the summer and fall. Overall objectives were to (1) evaluate the effectiveness of a fishway modification in reducing fishway fallout, (2) assess effects of spill, powerhouse operation, and fishway conditions on passage at fishway entrances, (3) determine the accuracy of electronic tunnels in detecting directional passage and salmonid species, (4) determine if electronic tunnels delay passage or injure fish, and (5) evaluate the feasibility of using underwater video cameras at fishway entrances to monitor passage.

All objectives were accomplished, except there was no spill in 1992. The fishway modification was not effective at reducing fishway fallout, but appeared to exacerbate the problem. Entrances most used were the south shore and north shore entrances. Entrances least used were those along the face of the powerhouse. As more fish entered through the shore-based entrances, more fish fell out at the second north powerhouse entrance. Operation of fewer turbines at the south end of the powerhouse attracted more fish to the south shore entrance. More turbines on-line toward the north end of the powerhouse encouraged fish to use more northerly entrances. Fish fell out from the first and second north powerhouse entrances in greater proportions when either one of these entrances was open in conjunction with the third north powerhouse entrance. Directional counts generated by electronic tunnels were positively associated with counts generated by underwater video in the summer and fall, but the paired difference was usually significant. More fish were counted by tunnels in the summer and more fish were counted by video in the fall. Summer tunnel counts included non-salmonid species, particularly at the north shore and south shore entrances; summer tunnel counts of salmonids were highest at the combined floating orifice gates (upstream movement) and the north powerhouse entrances (downstream movement). Fall counts included fewer non-salmonid and more salmonid species. Greater numbers of salmonids passed into the fishway at the combined floating orifice gates and the south shore entrance; greater numbers fell out at the north powerhouse entrances and the floating orifice gates. Tunnel counts were registered by small fish or nothing. Tunnel accuracy varied by species, passage direction, and entrance. Fish collided with tunnels frequently as they passed out the fishway through the floating orifice gates and the north powerhouse entrances. More fish tended to approach, but not enter, the floating orifice gates and the north shore entrance than other entrances.

Camera performance was satisfactory under the environmental conditions present. The best images were obtained when the camera was side-mounted on the tunnel, directed downstream, at a depth of six or more feet and visibility four feet or greater. Average tape review time was 5.17 hours of tape per hour. We successfully designed and tested a camera frame for the south shore entrance.

# REPORT A

## Evaluation of Passage of Adult Salmon and Steelhead at Lower Granite Dam

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# SUMMARY

## Objectives for 1992

During 1992 we planned to (1) evaluate the effectiveness of a fishway modification ("fallout fence") in reducing fallout of adult salmonids from the fishway, and (2) assess use of and fallout through fishway entrances by adult salmonids under various conditions of spill, powerhouse, and fishway operations.

## Accomplishments in 1992

We accomplished Objectives 1 and 2 except that low spring flow in the Snake River precluded evaluation of spill patterns.

## Findings in 1992

Passage evaluation results from tunnel (spring) and video (summer and fall) data indicate that the fallout fence at north powerhouse Entrances 1 and 2 increased rather than reduced fallout. The south shore and north shore entrances were generally used the most during all seasons; usage at the floating orifice gates and north powerhouse entrances was low. Fallout at north powerhouse Entrance 2 was strongly associated with use at the south shore and north shore entrances. Relative use and fallout were generally higher at the south shore entrance and lower at the north shore entrance when fewer turbines were in operation; when additional units were brought on-line, relative use and fallout were generally lower at the south shore entrance and higher at the north shore entrance. Counts in the downstream direction were always greater through north powerhouse Entrance 1 or 2 when combined with north powerhouse Entrance 3 than when combined with each other.

## INTRODUCTION

### Background

Adult salmon and steelhead migrating to their natal streams in the Snake River Basin must pass eight dams and reservoirs, four each in the lower Columbia and Snake rivers. The Columbia River watershed historically produced more chinook salmon (*Oncorhynchus tsawytscha*) than any other river system in the world, with a majority of some stocks coming from the Snake River Basin (Fulton 1968; Netboy 1980; Williams 1989). However, stocks of Snake River chinook salmon and sockeye salmon (*O. nerka*) have recently become so depleted (United States Army Corps of Engineers 1990, 1991) that they have been listed as threatened and endangered, respectively. Passage efficiency and effectiveness must be optimized to reduce salmon losses and delays at each dam. This study was developed in response to the high priority assigned to adult passage research in the Snake River by the U.S. Army Corps of Engineers through the Fish Research Needs and Priorities Subcommittee of the Fish Passage Development and Evaluation Program.

This study is identified in, and supported by, the Northwest Power Planning Council's 1987 Columbia River Basin Fish and Wildlife Program, which states that the Corps of Engineers shall conduct studies to determine the effects of reduced and instantaneous flows on adult fish. The need to evaluate spill criteria, which was developed 25 years ago under less-than-ideal conditions, has been recognized. Also included in the program is the need to study flows at fishway entrances to determine the best flows and operation conditions for enhancing adult passage.

Research has been conducted in the past by various agencies to evaluate use of and fallout through fishway entrances by adult salmonids (Johnson et al. 1979, 1982; Turner et al. 1983, 1984). However, additional studies were needed to better define use and fallout from fishways because studies at the lower Snake River dams were conducted during only a part of the migration season and with an incomplete range of flow conditions. Following recommendations made by Turner (1983), fishways were modified at Little Goose and Lower Granite dams in winter 1991 in an effort to reduce fallout. These modifications needed to be evaluated.

In 1991, we used electronic tunnels in all fishway entrances at Lower Granite and Little Goose dams to estimate entry and fallout through the entrances (Knutsen and Knapp 1992). We looked at relationships between entrance use and fallout and powerhouse and fishway operations, and evaluated the effectiveness of a fishway modification (fallout fence) in reducing numbers of fish that fall out through certain entrances. Low spring flow in the Snake River in 1991 precluded evaluating effects of quantity and pattern of spill on entrance use.

Results from our 1991 research indicated that the fallout fences did not appear to prevent or reduce fallout of adult salmon or steelhead through north powerhouse Entrances 1 and 2 at Little Goose or Lower Granite dams. At Little Goose Dam, the south shore entrance was the most used, although its use appeared to vary with changes in powerhouse operation. At Lower Granite Dam, the north shore entrance was most used; there was no apparent relationship between its use and changes in powerhouse operation. In general, the floating

orifice gates received little use and had very low levels of fallout. We found that north powerhouse Entrances 1 and 2 at both dams received little use and had relatively high levels of fallout. Use of north powerhouse Entrance 3 appeared to be greatest during the fall at both dams.

Because of equipment malfunctions, apparent count inacuracies, and the presence of non-target species (e.g. carp, suckers, shad) in the fishways during the 1991 study period, we surmised that tunnel counts were not always reliable. Although electronic impedance tunnels have been used extensively in the past (Johnson et al. 1979, 1982; Turner et al. 1983, 1984), little effort has been made to critically evaluate their performance under actual field conditions. Therefore, we subsequently tested in fall 1991 a system using low-light underwater video cameras as a means to verify tunnel counts. Our results indicated that underwater video cameras could successfully monitor fish passage at fishway entrances under most environmental conditions at the dam. The technology evaluation report (**Report B**) examines the accuracies of electronic tunnels and underwater video cameras as methods of enumerating passage of adult anadromous salmonids at fishway entrances.

The focus of this passage evaluation report (**Report A**) is to quantitatively and statistically examine relationships between powerhouse and fishway operations and use of and fallout through fishway entrances by adult chinook salmon and steelhead (*O. mykiss*) at Lower Granite Dam. Passage evaluation objectives for 1992 were to (1) evaluate the effectiveness of the fallout fence in reducing fallout of adult salmonids from the fishway and, (2) assess the effects of spill, powerhouse, and fishway operations on fishway entrance use and fallout by adult salmonids. All objectives were completed except that low spring flow in the Snake River precluded evaluation of spill patterns.

## Study Site

Lower Granite Dam is located on the Snake River in eastern Washington at River Mile 107.5. The project includes a 656-foot-long powerhouse containing six generator units, a spillway with eight spillbays, a juvenile fish collection facility, a navigation lock, and an adult fish collection system (Figure 1). The adult fish collection system consists of a continuous channel under the spillway and along the powerhouse. Fish enter the collection system through entrances located at (1) the north end of the spillway (north shore Entrances 1 and 2); (2) the north end of the powerhouse (north powerhouse Entrances 1, 2 and 3); (3) the face of the powerhouse (Floating Orifice Gates 1, 4, 7 and 10); and (4) the south end of the powerhouse (south shore Entrances 1 and 2; Figure 1).

North shore Entrances 1 (NSE-1) and 2 (NSE-2) are 6-foot-wide slots with overflow weirs submerged eight feet (submergences are expressed in relation to tailwater). NSE-1 and NSE-2 are oriented downstream and open to a 17.5-foot-wide lighted tunnel that passes through the spillway to the north end of the powerhouse. North powerhouse Entrances 1 (NPE-1) and 2 (NPE-2) are 6 feet wide with 8-foot-deep overflow weirs and are oriented downstream; NPE-1 is the southernmost north powerhouse entrance. North powerhouse Entrance 3 (NPE-3) is a 6-foot-wide entrance (with no overflow weir) oriented toward the spill basin and is the northernmost powerhouse entrance. The floating orifice

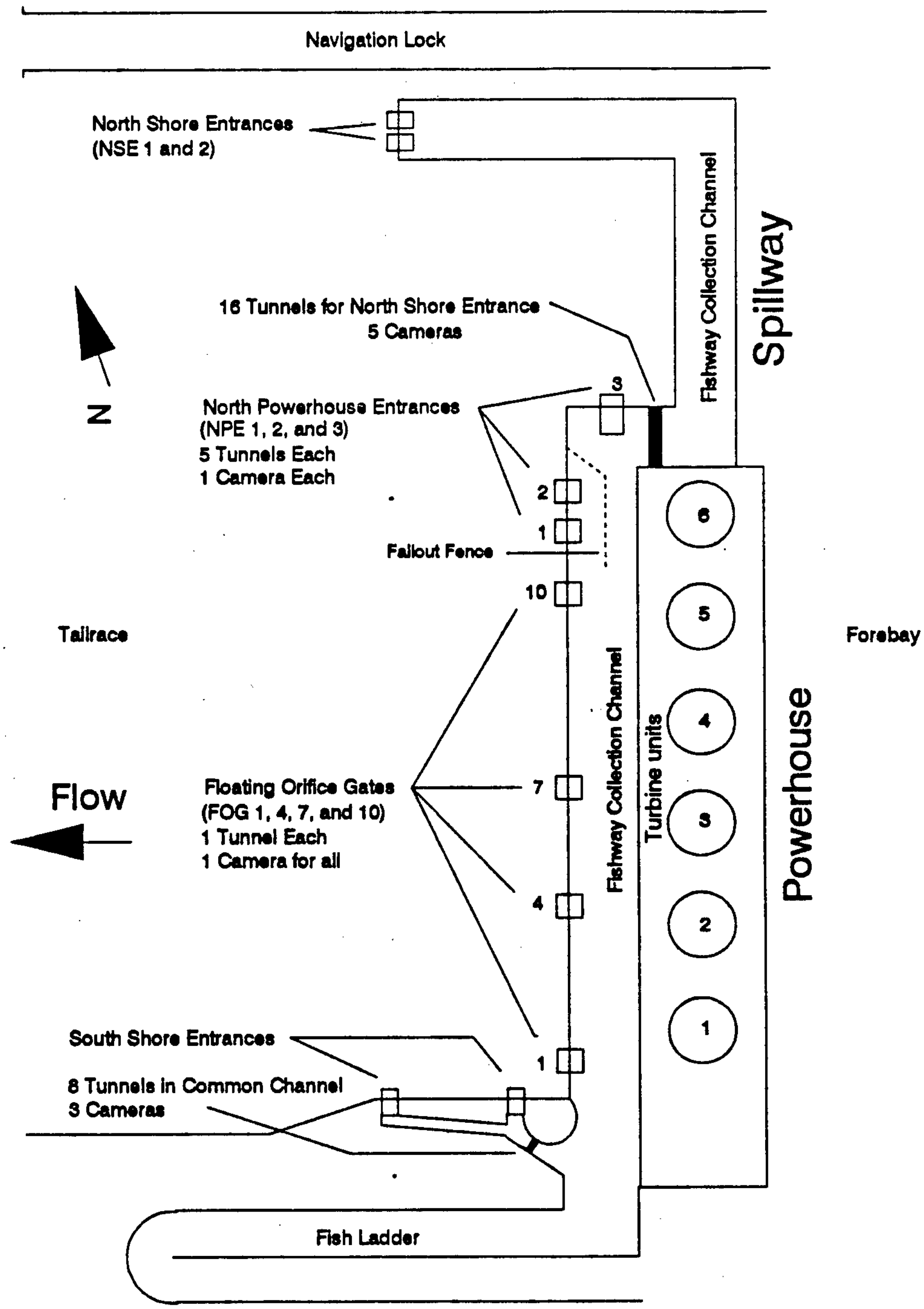


Figure 1. Location of fishway entrances, electronic tunnels, video cameras, and "fallout fence" at Lower Granite Dam, Snake River, 1992.

gates (FOGs) adjust automatically to fluctuations in tailwater elevation to maintain a 2- by 6-foot opening submerged approximately four feet below tailwater. South shore Entrances 1 (SSE-1) and 2 (SSE-2) are 4 feet wide with overflow weirs submerged six feet. SSE-1 and SSE-2 are approximately 88-feet apart, are oriented northward, and open to a 17.5-foot-wide channel that connects to the main collection channel near the base of the fish ladder on the south shore (Figure 1). The fish ladder is 16 feet wide with a 1 on 10 slope and an 8-foot water depth, rising approximately 100 vertical feet. Auxiliary water is supplied to the collection system by three electric pumps with pump intakes located near the south shore entrances.

The fallout fence installed in the collection channel at NPE-1 and NPE-2 was designed to direct fish entering NSE-1, NSE-2, and NPE-3 around the outflow from NPE-1 and NPE-2 (*see* Figure 1). The fence is 16 feet high and constructed of 3-inch diameter metal piping and PVC-coated chain-link fencing.

## METHODS

### Equipment

We used electronic impedance tunnels and low-light underwater video cameras to monitor passage of adult salmonids into and out of fishway entrances.

#### Electronic Tunnels

Electronic balanced-bridge impedance tunnels were installed in most fishway entrances so that a fish must pass through them when entering or exiting the fishway. Electronic tunnels were also installed in the collection channel when entrance-specific installation was not possible (NSE and SSE). The disadvantage to this location was that fish movement through these tunnels did not completely reflect true fishway entrance or exit into the tailrace. We used two types of electronic balanced-bridge impedance tunnels. Center-electrode tunnels contained two electrode pairs placed in the center of the tunnel and were installed in the floating orifice gate entrances. Peripheral-electrode tunnels contained two electrode pairs placed peripherally at the top and bottom of the tunnel and were installed in the remaining entrances. Peripheral-electrode tunnels were fabricated from 3/4-inch marine grade plywood and were 3 feet deep with a 1.5-foot by 6-foot opening. Center-electrode tunnels, fabricated from 16-gauge perforated stainless steel, were 3 feet deep with a 2-foot by 6-foot opening. The two electrode pairs produced separate low voltage currents in the upstream and downstream halves of the tunnels. To isolate the electrical fields in the tunnels between electrode pairs, we coated the tunnel surface with a non-conductive electrical insulating paint.

Each tunnel electrode pair was wired to a corresponding electronic fish detector (Smith Root, Model 602-A) via RG-58 coaxial cable (Figure 2). A detector contained resistive and capacitive integrated circuitry that, along with the resistance of the water between an electrode pair, made up four arms of a balanced bridge (Liscom and Volz 1974). Fish detectors tallied upstream and downstream counts as fish passed through the electronic tunnel. Each

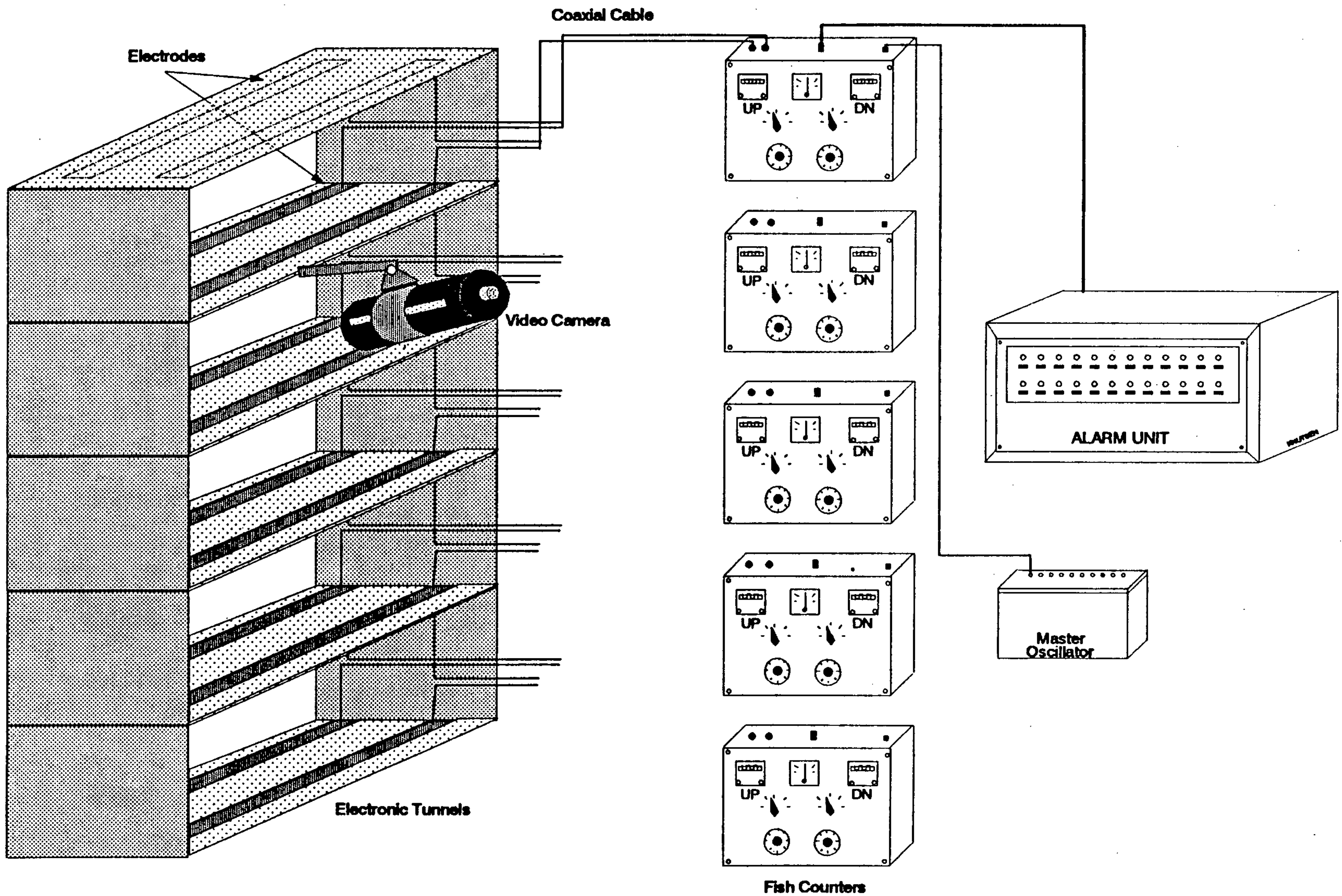


Figure 2. Schematic of the video camera and electronic fish detection system including electronic impedance tunnels, fish counters, alarm unit, master oscillator, and video camera.

detector was wired to a Model AL-600 Smith Root Inc. alarm unit. When a detector bridge became unbalanced for several seconds, an alarm unit would sense the imbalance and an audio or visual alarm was activated.

Because the body of a fish has a lower resistance to the alternating current than water, fish passing through a tunnel create an imbalance in the impedance bridge. A logic circuit in the fish counter senses the imbalance and, depending on the sequence of the upstream-downstream imbalances, records an "up" or "down" count on the tally register of the detector. To register an upstream or downstream count, the imbalances must occur within a 3-second interval of each other and be greater than the preset threshold level. We determined a near appropriate bridge sensitivity for counting fish greater than 20-inches fork length by passing dead adult salmonids of various lengths through electronic tunnels and documenting the sensitivity setting (30 microamps) at which fish greater than 20 inches would be counted. The sensitivity setting was approximate due to the difference in body resistance, body density, and swimming characteristics of dead fish versus live fish.

We installed multiple tunnels in metal frames wherever more than one tunnel was required to adequately encompass and monitor passage through a fishway entrance (Figure 3). Tunnel frames were fabricated of welded channel iron, angle iron, and flat bar, and contained galleries and clasps for protecting and securing the coaxial cable. We used PVC-coated chain-link fencing to prevent fish from passing over the top of the multiple tunnel configuration. At fishway entrances where multiple tunnels were present, fish

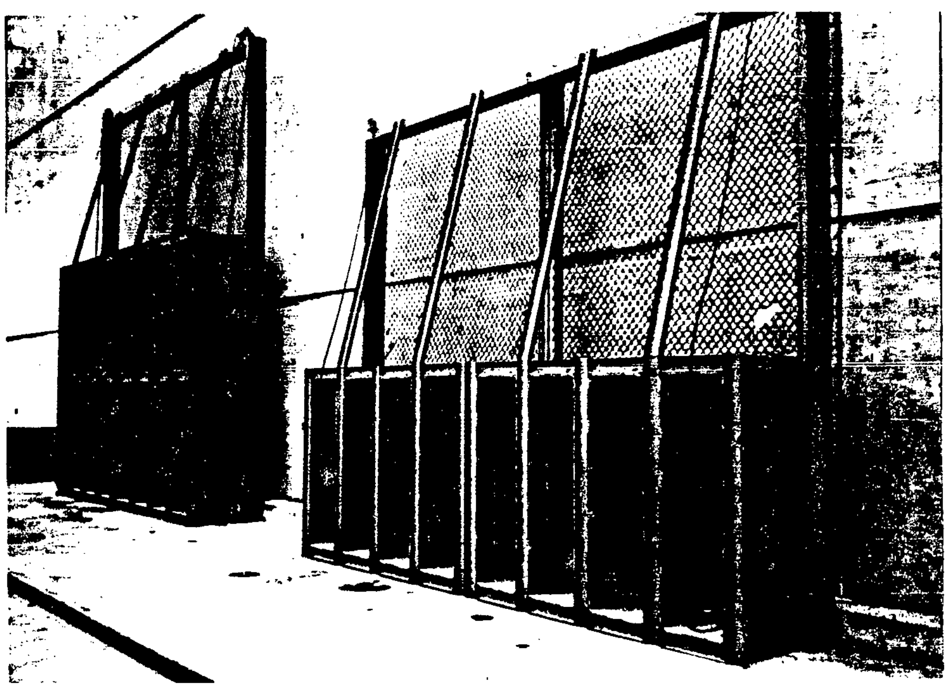

Figure 3. Multiple electronic tunnel assemblies for monitoring fish passage from the north (left) and south shore (right) fishway entrances at Lower Granite Dam, Snake River, 1992.

detectors were wired to a master oscillator (Figure 2). The master oscillator set the alternating current for each tunnel in phase (1 khz), which minimized interference between adjacent tunnels.

We installed eight tunnels in the common channel upstream of SSE-1 and SSE-2, one center-electrode tunnel in floating orifice Gates 1, 4, 7 and 10, five tunnels each in NPE-1, NPE-2, and NPE-3, and 16 tunnels in the collection channel south of NSE-1 and NSE-2 (*see* Figure 1).

Tunnels were installed into the fishway during April 1992. Preseason installation and inseason inspection of all tunnel assemblies required crane service and assistance from Corps of Engineer project personnel.

### Video Cameras

We used 11 underwater video SIT (silicon intensifier target) cameras (HydroVision/Photosea Inc.) to monitor passage through randomly selected electronic tunnels at various entrances (Figure 4). The SIT cameras were low-

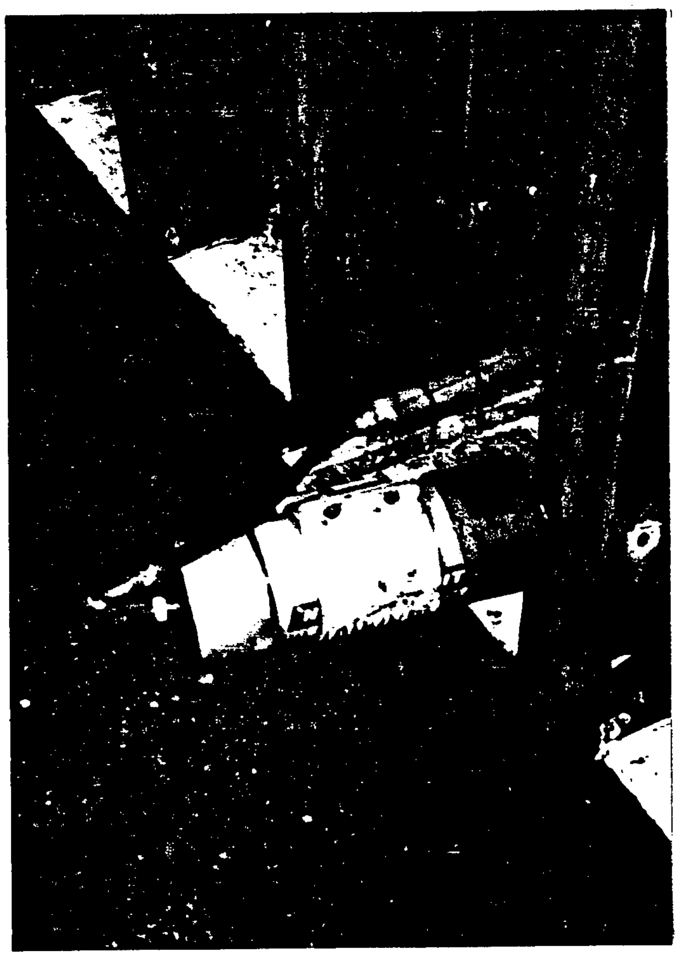

Figure 4. Low-light underwater video camera mounted on an electronic impedance tunnel at Lower Granite Dam, Snake River, 1992.

light level cameras developed to provide high resolution television display under illumination conditions as low as $10^{-5}$ footcandles. Cameras were 12 inches long and 4 inches in diameter and weighed 6.8 pounds. They were specially fitted with a PVC housing and a 110-degree wide-angle lens that provided a fixed-focus imaging range from 6 inches to infinity. The wide-angle lens allowed for full coverage of individual electronic tunnels.

We attached cameras to electronic tunnel frames via a specially designed metal bracket that enabled adjustment of the camera's imaging angle, distance from the tunnel perimeter, and vertical and horizontal orientation to the tunnel (Figure 4). Each camera was connected to a power supply containing a video output jack. Each power supply was connected to a Panasonic Model AG-6030 time-lapse VCR, via RG-59 (75-ohm) coaxial cable, for the purpose of recording fish passage. The time-lapse VCRs recorded at times ranging from 2 to 480 hours on a single 2-hour VHS video depending upon the velocity of the water at the tunnel location. We used 24-hour mode for recording at the NPEs and FOGs because the high water velocity caused fish to enter and exit at a greater speed. We recorded on a 48-hour mode at the SSE and NSE locations because of slower water velocities and fish movement. Standard VHS T-120 video tapes were used for all recordings.

Video tapes were reviewed and fish counts were enumerated using editing VCRs, and black and white monitors. The playback VCRs enabled personnel to stop the frame and slow advance or reverse while viewing the tape.

Video cameras were installed in early June, and the number of cameras allotted to a fishway entrance varied among entrances. Video cameras were mounted on one of two or three accessible tunnels in NPE-1 and NPE-2 to specifically verify fallout counts as part of the assessment of fallout fence effectiveness. Although five tunnels were stacked vertically at NPE-1 and NPE-2, the bottom two or three tunnels were usually blocked by a concrete lip when tailwater elevations were low, rendering them inaccessible to fish passage. In general, the top two tunnels were accessible during the summer period (11 June - 22 July) and the top three tunnels were accessible during the fall period (9 September - 10 November). We were unable to place cameras at NPE-3 because accessibility to the tunnel location was not possible without dewatering the fishway. We mounted five cameras in the NSE (Figure 5) and three cameras in the SSE tunnel frames, monitoring approximately one-third of the tunnels. One camera was installed in a FOG and rotated among the four open FOGs throughout the study.

## Procedures

### Camera Rotations

At the NSE and SSE multiple tunnel assemblies, we stratified the tunnels according to high or low activity levels to assign cameras and create homogenous strata for improved camera sampling. Activity levels were defined as the total of upstream and downstream electronic tunnel counts per individual tunnel. High and low use strata were delineated using the "cumulative square root of the frequency method" (Scheaffer et al. 1979).

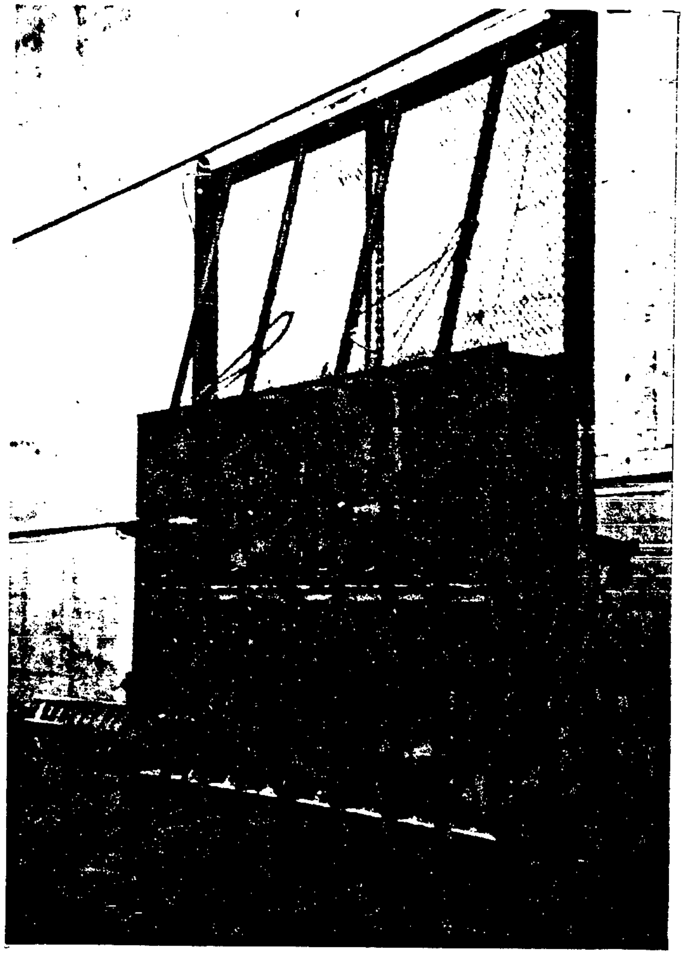

Figure 5. Multiple electronic tunnel assembly, with mounted low-light video cameras, monitoring passage from the north shore fishway entrance at Lower Granite Dam, Snake River, 1992.

The proportion of allotted cameras assigned to a given stratum at SSE (three cameras) and NSE (five cameras) was equal to the proportion each stratum contributed to the total fish count. Initially, and every two weeks after, we assigned each tunnel to an activity level, using electronic tunnel counts collected during the preceding two weeks. Since we did not have any tunnel counts from the two-week period prior to the beginning of the fall 1992 study period, we used tunnel counts collected at Lower Granite Dam during fall 1991 to determine tunnel strata for the first fall rotation. Once strata were determined, we randomly selected tunnels within the strata (without replacement) for camera placement. If initially identified tunnel strata were incorrect in representing actual activity, tunnels were reassigned to strata based on their performance during that rotation (post-stratification). Post-stratifying should improve precision of passage estimates derived from video data.

## North Powerhouse Entrance Rotation

We varied weekly the combination of north powerhouse entrances that were open to determine whether entrance use and fallout varied at NPEs among combinations. Only two of the three north powerhouse entrances could be opened at any one time to maintain the criteria for fishway to tailwater head differential. We randomly selected the pair of entrances that were open for any given week with each of three weekly combinations comprising a block. The combinations were NPE-1 & 2, NPE-1 & 3, and NPE-2 & 3. At the end of Week 4 of the Fall period, a malfunction of the weir gate at NPE-2 required us to leave NPE-1 and NPE-3 open for Week 5, replacing the NPE-1 and NPE-2 combination.

## Quality Control

Electronic fish counters were rotated every week to reduce biases associated with differential fish-counter performance. In addition, we routinely used a volt-ohm meter to detect possible breaks or shorts in the coaxial-tunnel circuit, and to measure and adjust counter sensitivity to maintain an effective bridge sensitivity. We attached a tunnel simulator to fish counters to simulate upstream and downstream passages of fish, which allowed us to determine if the counter registers were functioning properly. To ensure proper performance of video cameras and time-lapse VCRs, we used a black and white monitor to check video images from each camera/VCR unit twice daily.

# Data Collection

## Electronic Tunnels

Data from electronic tunnels were collected seven days per week during daylight hours during the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods. These periods corresponded to the times of expected peak migrations of spring and summer chinook salmon and summer steelhead, respectively. Cumulative upstream and downstream counts for each fish detector were recorded at one-hour intervals from 0700 to 2000 hours (14-hour study day) from 29 April through 22 July 1992, and from 0800 to 1700 hours (10-hour study day) from 9 September through 10 November 1992. We used upstream counts to gauge use and downstream counts to ascertain fallout. After we recorded counts, we cleared the registers and, if necessary, rebalanced the resistive and capacitive circuitry bridge within the counter.

We assigned condition codes to all hourly electronic tunnel counts to indicate which counts were reliable. Conditions necessary for a count to be considered reliable included (1) the electronic tunnel remained in the water for the entire hour, (2) the counter remained in balance for at least 3/4 of the hour, and (3) interference from adjacent counters or other electronic equipment did not appear to trigger multiple false counts during the hour.

### Video Cameras

We recorded video images of fish passage during all hours of electronic tunnel operation during the summer and fall study periods. Tapes were changed every two to five days depending upon the record mode used. Video tapes were reviewed 10-14 hours per day, seven days per week, by up to two staff members at a time. During video tape review, we recorded upstream and downstream movement of target species, non-target species, and unknown species over one-hour intervals, corresponding to tunnel count hours. "Target" species were adult chinook salmon and steelhead, "non-target" species were as large as target species and included resident fish such as carp (*Cyprinus carpio*), and "unknown" species were unidentifiable fish of sufficient size to register electronic tunnel counts. We used the number of observed upstream and downstream target fish observations to ascertain entrance use and fallout, respectively.

### Powerhouse, Fishway, and Environmental Variables

To compare use and fallout with changes in powerhouse and fishway operations, we recorded project operation variables at one-hour intervals. Project information included (1) individual and total generator output (megawatts), (2) forebay and tailwater elevations (feet), (3) surface water velocity (fps) in the south shore and north powerhouse collection channel, and (4) fishway to tailwater elevation differential (feet). Surface water velocities were obtained by timing the traveling distance of bouyant wood chips thrown in the fishway. All other variables were collected from the powerhouse control room, fishway control board, or directly at the weir gates. We also obtained daily counts of fish passing the fish viewing window in the ladder and daily forebay water temperature from Corps personnel. We converted individual and total generator output from megawatts to thousands of cubic feet per second (kcfs) discharge to determine if daily upstream and dowstream counts at entrances were associated with daily discharge.

## Data Analysis

### Assessment of Missing or Incomplete Data

Tunnel and electronic fish counter malfunctions occasionally resulted in incomplete hourly entrance totals at tunnel locations. To estimate missing individual tunnel counts, we calculated a mean hourly count using all reliable counts from the affected tunnel recorded two hours before and two hours after the missing count. Restricting estimates to a two-hour range minimized biases associated with possible diel passage patterns and changes in turbine operations. If no reliable counts existed for the affected tunnel within the two-hour range, we calculated a mean hourly count from adjacent tunnels, using counts recorded during the affected time period. If it was not possible to use either method, data was treated as missing for that hour(s) and not considered for analysis.

We computed the proportion of tunnel counts per entrance that were estimated by dividing estimated hours by total tunnel hours. Total tunnel

hours were derived from the number of tunnels per entrance, the hours monitored per day, the number of days per week, and the number of weeks.

Missing fish passage data was also generated as a result of occasional video equipment malfunctions. The proportion of missing video hours was computed by dividing the sum of hours lost for all video cameras per entrance by total video hours. Total video hours were derived in the same manner as total tunnel hours.

## Fallout Index

We used tunnel counts to calculate an index of fallout (TFALL) for all entrances during the spring period (29 April - 10 June), as described by Turner et al. 1983:

$$TFALL = DOWN/UP$$

where

DOWN = total of downstream counts for a given entrance for a given time period, and

UP = total of upstream counts for a given entrance for a given time period.

An index value > 1 represented more down than up counts, whereas an index value < 1 represented more up than down counts. We qualitatively compared fallout indices at NPE-1 and NPE-2 with those reported from 1981 (Turner et al. 1983) and 1991 (Knutsen and Knapp 1992) to determine if the fallout fence was effective at reducing fallout. Fallout indices were also compared at other entrances between 1981, 1991, and 1992.

## Entrance Use and Fallout

For estimates of entrance use and fallout during the spring, we used data collected from electronic tunnel counts because that was the only technology available to us during that period. Although electronic tunnel counts were available for the summer and fall periods, analyses are limited to video data; technology evaluations (**Report B**) indicated that tunnel counts were unreliable when large numbers of non-target fish were present during those periods.

**Electronic Tunnel Counts:** To derive total daily upstream and downstream electronic tunnel counts at each fishway entrance, we added the upstream and downstream counts from all tunnels within an entrance for each hour that electronic tunnel counts were available or estimated during each day. If total counts at an entrance were based on less than the number of designated study hours for a day in that study period (14 hours spring and summer; 10 hours fall), entrance counts were expanded as:

$$\text{Expanded entrance count} = (\text{mean count/hour})(\text{total hours})$$

where

Mean count/hour = the total number of upstream or downstream fish counted at a given entrance divided by the number of actual counting hours and,

Total hours = the total number of designated counting hours in a day for a given study period.

**Video Counts:** To determine daily upstream and downstream counts from video data, we first determined the proportion of unidentifiable fish observations that could be target fish species. To do so, we assumed that the ratio of target to non-target fish in identifiable observations would be similar for unidentifiable observations. Therefore, we distributed unidentifiable fish counts for each hour according to the identified target/non-target ratio observed during that hour. If we had observations of unidentifiable fish, but no target and non-target fish counts for an hour, then unidentifiable observations were left as "unknown."

Derivation of daily entrance totals from video data was a 3-step process: (1) video counts per monitored tunnel within a two-week time strata of low or high use were adjusted to a 14-hour (summer) or 10-hour (fall) daily total, (2) adjusted video counts were expanded by the total number of tunnels within the high or low use stratum, or entire entrance if not stratified, and (3) totals for each activity stratum were summed for an entrance total.

To adjust the video data to the designated number of study hours within a day, we expanded video counts from each monitored tunnel as performed for the electronic tunnel counts for each entrance.

To determine daily totals of upstream and downstream video counts per stratum, actual or day-adjusted video counts were multiplied by the number of tunnels in each stratum at that entrance. If more than one camera was used to monitor tunnels within a stratum, we calculated a mean upstream and downstream count for that stratum and multiplied the mean count by the number of tunnels in the stratum. We then summed daily directional passage counts from each stratum within an entrance to derive daily estimates of entrance use and fallout. As a result of the limited number of video cameras per entrance and occasional equipment malfunctions, we encountered situations at SSE and NSE where either high or low strata were not represented in video fish counts. If only one strata was represented within one of these entrances, video counts from that strata were expanded to represent entrance passage.

The total number of tunnels within a stratum varied according to the rotation week, stratification results, and entrance. Northshore and southshore entrances were always stratified. Tunnels located at NPE-1 and NPE-2 were not stratified because only one camera was available for placement at those entrances. NPE video counts were expanded according to the number of tunnels accessible for fish passage (two tunnels summer period, three tunnels fall period). It was not necessary to expand counts at the FOGs as the field of view encompassed the entire entrance and counts represented total passage.

**Tunnel and Video Counts:** We calculated absolute and/or relative estimates of entrance use and fallout on a daily basis and computed median, minimum, maximum, and standard deviation values on a seasonal or weekly basis.

Absolute counts were based on actual or estimated daily upstream and downstream entrance totals. Since absolute counts were likely influenced by the size of the run passing the dam, we estimated the proportion each entrance count (upstream and downstream) contributed to the total upstream and downstream count from all entrances per day (relative passage). Relative estimates of entrance use (upstream count) or fallout (downstream count) were used in most of our analyses.

Non-parametric procedures were used for statistical analyses since the tunnel and video data did not consistently meet the assumptions of normality and equal variances. We chose as our significance level a P value of $< 0.05$. All testing was completed using procedures in the SAS program for personal computers (SAS Institute Inc. 1990).

## Seasonal Passage at Entrances

To identify the entrances that were most used, and where fallout most occurred during the spring, summer, and fall periods, we used electronic tunnel and video camera data to calculate relative median estimates of daily entrance use and fallout for each study period. For the video data, daily estimates of median passage were calculated on a weekly basis during the summer and fall periods because fishway conditions (e.g. NPE combinations) changed on a weekly basis and camera distributions changed on a biweekly basis. These weekly changes compromised between week comparisons of relative passage estimates at entrances.

For purposes of statistical analysis, we grouped entrances according to similar characteristics and/or locations along the fishway during each season. We considered SSE and NSE as individual entrances, grouped all FOGs (1, 4, 7, and 10), and grouped all NPEs (1, 2, and 3). We totaled upstream and downstream counts from entrance groupings as though they represented a single entrance count. Grouping of entrance counts provided an increased sample size (days) at entrances where monitoring was not continuous (FOGs, NPEs). Grouping entrances ensured that groups were represented by at least one entrance when using video data, which allowed us to conduct an overall seasonal evaluation.

We used the Kruskal-Wallis test to determine whether the distribution of a daily passage estimate (use or fallout) had the same location parameter across the four entrance groupings. Tests were conducted for each seasonal period. A non-parametric analogue to the T-test (Tukey) was used to conduct multiple comparisons if analysis of variance test results were significant.

## Powerhouse, Fishway, and Environmental Variables

We computed non-parametric multiple correlations, using the Spearman Rank procedure, to determine whether daily entrance use and fallout were associated with each other and with specific operational and environmental variables. Ranking procedures were used to compensate for non-linear associations and/or non-normal variables. Variables used in the correlations included (1) mean daily upstream and downstream counts per entrance, (2) total daily upstream and downstream counts from all entrances, (3) daily net (upstream -

downstream) counts from all entrances, (4) mean hourly powerhouse discharge (kcfs) per day, (5) surface water velocity (fps) in the southshore and north powerhouse sections of the fish collection channel, (6) daily water temperatures, and (7) daily fish counts at the fish viewing window. We used $P < 0.05$ as our level of significance.

## Turbine Operation Evaluation

We evaluated fish passage under varying powerhouse operations during each seasonal period to determine possible operational effects on entrance use and fallout. The sequence of turbine units that were in operation for at least one hour comprised a set of turbine operations. In general, turbine operations began with Unit 1 and progressed in sequential order to a full complement of six turbines in operation. Since some turbine operations occurred for only a few hours during a seasonal time period, we only looked at those that occurred more than 5% of the time during a given period. For a given operating scenario occurring greater than 5% of the time, we totaled the daily upstream and downstream fish counts occurring during that scenario, and divided those totals by the length of time (hours) the specific set of operations occurred; this resulted in a sampling unit of fish/hour/day/turbine operation. Since some operating scenarios were used more during certain portions of a season than others, and because daily fish run-size varied throughout each season, we calculated relative values to make possible within season, or within week, comparisons of entrance use and fallout between turbine operations.

We computed relative estimates of daily median entrance use and fallout for each turbine operation for the entire spring period and for each week of the summer and fall periods. Weekly estimates of relative passage were used for the video data in the summer and fall because (1) NPE combinations changed weekly, (2) camera locations differed biweekly, and (3) some turbine operations were not used during some weeks in a season.

We grouped the entrances according to similar locations along the fishway, as done for the seasonal evaluation, to determine if a significant difference in relative passage occurred for each entrance grouping as powerhouse operations changed. If possible, we selected the two turbine operations that represented extremes in turbine use (i.e. southern units operating vs. northern units operating) as our treatments to provide more definitive results. We used a non-parametric analogue to the two-sample T-test (Wilcoxon Rank Sum test) to test the hypothesis that the distributions of the relative passage estimates under the two turbine operations are the same across the grouped entrances. Tests were conducted for each season.

## North Powerhouse Entrance Evaluation

To determine the combination of two north powerhouse entrances that maximized use of and minimized fallout through each, we varied weekly the combination of two entrances that were open (*see* **Procedures**). We calculated median estimates of daily passage (absolute) for each open entrance under each NPE combination (treatment). Each NPE combination was to be selected at random and occur for one week within a three-week block; spring and summer

seasons contained two blocks and fall contained three blocks. Blocking was used to factor out the confounding effects of run size. After ranking the data, an analysis of variance with a block design was used to test primarily whether median estimates of entrance use and fallout had the same distribution between treatments (combinations), and secondarily between blocks.

We were not able to compare median estimates of daily entrance use and fallout at NPE-3 during the summer and fall study periods because cameras could not be installed at that entrance.

## RESULTS

### Assessment of Missing or Incomplete Data

As a result of malfunctions in two of the NPE-3 tunnels, we estimated approximately two-thirds of those electronic tunnel counts during each study period. The proportion of hourly tunnel counts that were estimated at other entrances ranged from 0% (NSE) to 7% (SSE) during the spring and summer periods and from 0% (FOG-4, -7, and -10) to 4% (NPE-1) during the fall period. The majority of estimated tunnel hours per entrance was less than 1% of the total tunnel hours during each seasonal period.

The proportion of video hours lost also varied seasonally and among fishway entrances. Video hours lost during the summer period ranged from < 1% (FOG-4) to 9% (SSE). The majority of hours lost during this period were a result of problems with image oscillations due to camera malfunctions, which were subsequently corrected. Video hours lost during the fall period ranged from 0% (FOG-10) to 20% (FOG-7), and were primarily a result of dark conditions within the fishway during the final days of the study period when the solar angle shifted.

### Fallout Index

The fallout index was over two times greater for the NPEs during 1992 (262% of up counts) than in either 1981 or 1991 (Figure 6). The fallout index was also higher at SSE, where down counts totaled 140% of up counts, compared with 1981 and 1991 where down counts totaled 63% and 78% of up counts, respectively. The ratio of down counts to up counts at NSE (54%) was comparable to that observed during 1981, but lower than that observed during 1991. Fallout was lowest at the FOGs during all three study years.

### Seasonal Passage at Entrances

Relative and absolute upstream and downstream fish counts from electronic tunnels were highest at the shore entrances (SSE and NSE) during the spring period (Table 1; **APPENDIX A** , respectively). NSE received the greatest proportion of upstream counts and SSE received the greatest proportion of downstream counts during this period. In general, upstream counts at the FOGs and NPEs were proportionately low, but the percent of downstream counts at the NPEs, especially NPE-2, were higher than at the FOGs (Table 1).

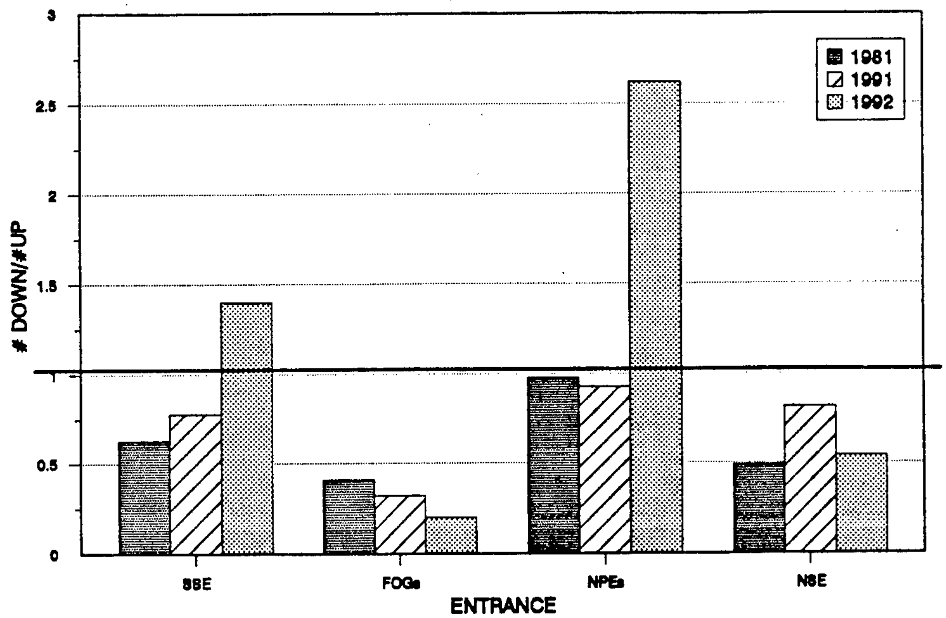


Figure 6. Fallout indices, as calculated by Turner et al. (1983) for fishway entrances during spring 1981 (20 April - 12 June), spring 1991 (24 April - 5 June), and spring 1992 (29 April - 10 June) at Lower Granite Dam, Snake River.

Table 1. Relative median, minimum, maximum, and standard deviation values for total daily upstream and downstream fish counts at fishway entrances during the spring period (29 April - 10 June) at Lower Granite Dam, Snake River, 1992. Data is from electronic tunnels.

| | | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Percent | | | | Percent | | | |
| Entrance | *N* (days) | Median | Min | Max | SD | Median | Min | Max | SD |
| SSE | 48 | 29.84 | 5 | 59 | 10.34 | 40.41 | 7 | 73 | 19.07 |
| FOG-1 | 48 | 2.33 | 0 | 35 | 5.76 | 1.23 | 0 | 4 | 0.94 |
| FOG-4 | 48 | 4.74 | 1 | 17 | 3.30 | 0.62 | 0 | 3 | 0.60 |
| FOG-7 | 48 | 5.00 | 1 | 22 | 5.15 | 0.62 | 0 | 4 | 0.69 |
| FOG-10 | 48 | 2.26 | 0 | 13 | 3.06 | 0.53 | 0 | 3 | 0.58 |
| NPE-1 | 32 | 2.69 | 0 | 10 | 2.11 | 7.10 | 2 | 25 | 5.52 |
| NPE-2 | 32 | 2.43 | 0 | 14 | 3.24 | 10.21 | 4 | 39 | 8.73 |
| NPE-3 | 32 | 1.63 | 0 | 16 | 3.35 | 1.34 | 0 | 18 | 3.94 |
| NSE | 48 | 36.20 | 10 | 63 | 13.10 | 25.51 | 8 | 61 | 13.53 |

During the weeks of the summer period, relative and absolute upstream counts at NSE were usually higher than all other video-monitored entrances (Table 2; **APPENDIX A**, respectively). SSE was usually the second most used entrance, but showed a progressive increase in the proportion of upstream counts toward summer's end (Table 2). NPE-1 and NPE-2 received little use. When open, relative downstream movement was always highest at NPE-2 during the summer period. Whenever NPE-2 was closed, relative fallout was highest at NSE (Week 8) or NPE-1 (Week 10). The FOGs had the lowest relative fallout during all weeks of the summer period.

During weeks of the fall period, SSE was usually the most used video-monitored entrance (Table 3; **APPENDIX A**), receiving relatively greater use as the season progressed. NSE was usually the second most used entrance, but the proportion of upstream counts decreased as the season progressed. The FOGs and NPEs received little use, except during Weeks 3 and 4 when FOG-1 had relatively high use. Downstream counts were proportionately high at NSE, SSE, NPE-1, and NPE-2, and interchanged dominance throughout the season; downstream counts were relatively low at the FOGs during all weeks of the fall period.

Results from non-parametric analysis of variance suggested that estimates of relative upstream and downstream passage were significantly different amongst entrance groupings during all study periods (Tables 4 and 5). Multiple comparison tests for the spring period indicated that all two-sample comparisons were significantly different. During the spring, relative use at NSE and relative fallout at SSE were significantly higher than relative use and fallout at other entrances, respectively. For the summer period, relative use at NSE and fallout at NPEs were significantly higher than relative use and fallout at the other entrances, respectively. However, during the fall, relative use at SSE was significantly greater than at the other entrances; relative fallout at the NPEs and SSE was significantly higher than other entrances, but not between each other.

Table 2. Relative median, minimum, maximum, and standard deviation values for total daily upstream and downstream fish counts at fishway entrances during weeks of the summer study period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992. Data is from video observations of adult salmonids.

| | | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Percent | | | | Percent | | | |
| Week, entrance | *N* (days) | Median | Min | Max | SD | Median | Min | Max | SD |
| Week 7, | | | | | | | | | |
| SSE | 6 | 14.95 | 7 | 30 | 9.71 | 14.02 | 3 | 21 | 6.84 |
| FOG-7 | 5 | 9.23 | 4 | 15 | 3.84 | 10.17 | 3 | 18 | 6.82 |
| NPE-1 | 6 | 0.28 | 0 | 2 | 0.72 | 1.21 | 0 | 5 | 1.82 |
| NPE-2 | 6 | 1.00 | 0 | 3 | 1.26 | 67.51 | 39 | 87 | 17.30 |
| NSE | 6 | 71.12 | 63 | 90 | 10.26 | 8.15 | 7 | 19 | 4.38 |
| Week 8, | | | | | | | | | |
| SSE | 6 | 10.25 | 6 | 21 | 5.24 | 3.94 | 0 | 19 | 6.79 |
| FOG-7 | 6 | 8.06 | 3 | 17 | 5.21 | 1.77 | 0 | 13 | 5.19 |
| NPE-1 | 6 | 0.80 | 0 | 2 | 0.89 | 10.98 | 4 | 23 | 7.46 |
| NSE | 6 | 80.73 | 69 | 87 | 6.66 | 76.80 | 66 | 94 | 10.56 |
| Week 9, | | | | | | | | | |
| SSE | 7 | 34.36 | 5 | 52 | 14.94 | 18.89 | 13 | 26 | 4.34 |
| FOG-1 | 7 | 5.89 | 2 | 17 | 5.26 | 2.30 | 0 | 8 | 2.56 |
| NPE-2 | 7 | 6.04 | 5 | 13 | 3.25 | 69.80 | 62 | 79 | 5.44 |
| NSE | 7 | 54.62 | 35 | 64 | 10.20 | 8.34 | 4 | 9 | 2.30 |
| Week 10, | | | | | | | | | |
| SSE | 6 | 43.66 | 19 | 55 | 12.29 | 24.45 | 12 | 52 | 14.49 |
| FOG-1 | 6 | 11.22 | 2 | 24 | 7.44 | 16.55 | 8 | 37 | 10.17 |
| NPE-1 | 6 | 0.55 | 0 | 1 | 0.42 | 52.90 | 21 | 66 | 18.39 |
| NSE | 6 | 43.48 | 33 | 67 | 11.44 | 6.10 | 2 | 21 | 6.71 |
| Week 11, | | | | | | | | | |
| SSE | 7 | 51.66 | 2 | 78 | 32.08 | 14.16 | 4 | 32 | 9.82 |
| FOG-4 | 7 | 10.59 | 0 | 22 | 8.24 | 1.43 | 0 | 17 | 6.19 |
| NPE-1 | 7 | 1.58 | 0 | 11 | 4.33 | 19.46 | 13 | 40 | 8.65 |
| NPE-2 | 7 | 0.00 | 0 | 7 | 2.74 | 47.36 | 14 | 69 | 19.52 |
| NSE | 7 | 22.73 | 12 | 92 | 35.23 | 10.09 | 3 | 43 | 13.45 |
| Week 12, | | | | | | | | | |
| SSE | 7 | 46.15 | 10 | 67 | 23.49 | 21.14 | 10 | 40 | 9.53 |
| FOG-4 | 7 | 13.95 | 0 | 26 | 9.80 | 7.81 | 0 | 36 | 12.99 |
| NPE-2 | 7 | 0.00 | 0 | 19 | 6.97 | 55.12 | 33 | 72 | 14.71 |
| NSE | 7 | 36.54 | 7 | 90 | 26.94 | 11.38 | 0 | 31 | 9.83 |

Table 3. Relative median, minimum, maximum, and standard deviation values for total daily upstream and downstream fish counts at fishway entrances during weeks of the fall study period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992. Data is from video observations of adult salmonids.

| | | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Percent | | | | Percent | | |
| Week, entrance | *N* (days) | Median | Min | Max | SD | Median | Min | Max | SD |
| Week 1, | | | | | | | | | |
| SSE | 7 | 29.28 | 18 | 48 | 9.93 | 12.66 | 6 | 17 | 4.20 |
| FOG-10 | 7 | 9.18 | 3 | 15 | 4.60 | 2.52 | 2 | 7 | 1.99 |
| NPE-1 | 7 | 2.16 | 0 | 7 | 2.38 | 17.67 | 5 | 34 | 10.61 |
| NPE-2 | 7 | 5.73 | 0 | 15 | 5.34 | 34.48 | 16 | 47 | 12.17 |
| NSE | 7 | 55.13 | 33 | 60 | 10.04 | 29.66 | 19 | 48 | 10.87 |
| Week 2, | | | | | | | | | |
| SSE | 7 | 52.81 | 47 | 64 | 6.76 | 10.82 | 5 | 16 | 4.24 |
| FOG-10 | 7 | 1.97 | 0 | 9 | 3.75 | 0.64 | 0 | 2 | 0.42 |
| NPE-1 | 5 | 0.50 | 0 | 3 | 1.07 | 26.24 | 18 | 47 | 11.99 |
| NSE | 7 | 39.03 | 32 | 53 | 7.42 | 62.72 | 46 | 88 | 15.87 |
| Week 3, | | | | | | | | | |
| SSE | 6 | 46.01 | 10 | 58 | 16.80 | 23.13 | 15 | 29 | 6.66 |
| FOG-1 | 3 | 24.44 | 15 | 29 | 6.88 | 3.39 | 3 | 4 | 0.55 |
| FOG-10 | 4 | 1.89 | 1 | 3 | 1.14 | 0.62 | 0 | 1 | 0.42 |
| NPE-2 | 6 | 2.74 | 1 | 5 | 1.23 | 36.02 | 20 | 52 | 13.76 |
| NSE | 6 | 40.08 | 23 | 60 | 13.60 | 38.75 | 28 | 49 | 7.21 |
| Week 4, | | | | | | | | | |
| SSE | 6 | 35.20 | 25 | 61 | 13.71 | 24.56 | 22 | 35 | 4.80 |
| FOG-1 | 6 | 19.53 | 4 | 38 | 13.79 | 3.36 | 3 | 4 | 0.74 |
| NPE-1 | 6 | 0.57 | 0 | 1 | 0.30 | 35.20 | 27 | 40 | 5.19 |
| NSE | 6 | 40.13 | 33 | 47 | 5.60 | 34.97 | 30 | 48 | 6.32 |
| Week 5, | | | | | | | | | |
| SSE | 7 | 63.25 | 37 | 80 | 13.21 | 62.55 | 23 | 70 | 16.42 |
| FOG-4 | 7 | 1.10 | 1 | 6 | 2.32 | 1.21 | 0 | 5 | 1.46 |
| NPE-1 | 7 | 0.00 | 0 | 1 | 0.36 | 20.13 | 13 | 28 | 6.43 |
| NSE | 7 | 30.17 | 10 | 40 | 10.35 | 8.11 | 5 | 30 | 8.73 |
| Week 6, | | | | | | | | | |
| SSE | 7 | 53.38 | 33 | 84 | 16.48 | 41.36 | 30 | 67 | 11.74 |
| FOG-4 | 7 | 3.52 | 1 | 9 | 2.57 | 1.48 | 1 | 4 | 1.06 |
| NPE-2 | 7 | 3.17 | 1 | 10 | 3.78 | 35.22 | 5 | 46 | 16.01 |
| NSE | 7 | 27.83 | 10 | 49 | 15.08 | 17.69 | 13 | 22 | 3.40 |
| Week 7, | | | | | | | | | |
| SSE | 7 | 61.75 | 51 | 80 | 10.54 | 22.01 | 18 | 34 | 5.97 |

Table 3. Continued.

| Week, entrance | N (days) | Upstream counts |  |  |  | Downstream counts |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Percent |  |  |  | Percent |  |  |  |
|  |  | Median | Min | Max | SD | Median | Min | Max | SD |
| FOG-7 | 7 | 0.43 | 0 | 3 | 0.98 | 0.24 | 0 | 1 | 0.26 |
| NPE-1 | 7 | 10.24 | 4 | 19 | 4.70 | 19.68 | 15 | 31 | 6.61 |
| NPE-2 | 7 | 5.05 | 1 | 14 | 4.93 | 31.81 | 14 | 42 | 10.84 |
| NSE | 7 | 17.63 | 13 | 25 | 3.87 | 20.28 | 8 | 44 | 11.60 |
| Week 8, |  |  |  |  |  |  |  |  |  |
| SSE | 7 | 80.49 | 67 | 84 | 7.72 | 52.00 | 40 | 60 | 7.24 |
| FOG-7 | 7 | 2.27 | 0 | 3 | 0.95 | 0.32 | 0 | 1 | 0.61 |
| NPE-1 | 7 | 7.78 | 3 | 11 | 3.21 | 29.82 | 20 | 45 | 7.61 |
| NSE | 7 | 14.39 | 2 | 27 | 9.54 | 16.25 | 10 | 28 | 5.95 |
| Week 9, |  |  |  |  |  |  |  |  |  |
| SSE | 6 | 94.04 | 85 | 97 | 4.16 | 78.37 | 52 | 85 | 11.69 |
| FOG-7 | 6 | 0.00 | 0 | 0 | 0.16 | 0.31 | 0 | 1 | 0.47 |
| NPE-2 | 6 | 1.36 | 0 | 4 | 1.31 | 17.31 | 12 | 28 | 5.90 |
| NSE | 6 | 3.96 | 2 | 12 | 3.76 | 4.30 | 3 | 20 | 6.49 |

Table 4. Mean score, Chi-square statistic, and *P*-values for non-parametric analysis of variance (Kruskal-Wallis test), per entrance grouping by season, of relative daily <u>upstream</u> fish counts during the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992. Mean scores with the same letter within a season indicate no significant difference in entrance use, as per Tukey's studentized range test.

| Season | Entrance mean score |  |  |  | *N* (days) | Chi-square statistic | *P* |
|---|---|---|---|---|---|---|---|
|  | SSE | FOGs | NPEs | NSE |  |  |  |
| Spring[a] | $124.18_y$ | $86.44_x$ | $31.56_w$ | $143.82_z$ | 48 | 113.84 | 0.0001 |
| Summer[b] | $96.84_y$ | $56.46_x$ | $30.09_w$ | $122.61_z$ | 38 | 99.99 | 0.0001 |
| Fall[b] | $190.75_z$ | $62.75_x$ | $63.06_x$ | $141.44_y$ | 57 | 155.46 | 0.0001 |

[a] *Passage counts calculated from electronic tunnel data.*
[b] *Passage counts calculated from video camera data.*

Table 5. Mean score, Chi-square statistic, and *P*-values for non-parametric analysis of variance (Kruskal-Wallis test), per entrance grouping by season, of relative daily downstream fish counts during the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992. Mean scores with the same letter within a season indicate no significant difference in entrance fallout, as per Tukey's studentized range test.

| Season | Entrance mean score SSE | FOGs | NPEs | NSE | *N* (days) | Chi-square statistic | *P* |
|---|---|---|---|---|---|---|---|
| Spring[a] | $150.66_z$ | $25.58_w$ | $90.09_x$ | $119.67_z$ | 48 | 132.74 | 0.0001 |
| Summer[b] | $76.18_y$ | $42.68_x$ | $119.75_z$ | $67.38_y$ | 38 | 60.74 | .0001 |
| Fall[b] | $150.75_z$ | $29.81_x$ | $152.28_z$ | $125.17_y$ | 57 | 131.78 | .0001 |

[a] *Passage counts calculated from electronic tunnel data.*
[b] *Passage counts calculated from video camera data.*

### Powerhouse, Fishway, and Environmental Variables

We did not observe a consistently strong relationship between mean hourly discharge (kcfs) and other variables among study periods (**APPENDIX B**). However, we did see a positive correlation between discharge and fish counts at the viewing window (r = .60, P = 0.0001)) and net electronic tunnel counts (r = .61. P = 0.0001)) during the spring period.

A positive correlation was evident between water temperature and fallout at NPE-2 and NPE-1 during the spring (r = .72, P = 0.0001) and summer (r = .79, P = 0.0001) periods, respectively. However the strength of the association was less during the fall period (NPE-1, r = 0.21, P = 0.21; NPE-2, r = 0.15, P = 0.40).

Fish counts at the viewing window were strongly associated with total entrance upstream counts during the fall period (r = .86, P = 0.0001).

In general, upstream and downstream counts at each fishway entrance were strongly associated with each other during all study periods. Downstream counts at NPE-2 and/or NPE-1 were strongly associated with upstream counts at NSE and SSE for all seasons. Upstream counts at NSE and SSE were always strongly associated with each other and with total upstream counts, but the same relationships were not always true for downstream counts at these entrances. Downstream counts at FOG-1 were strongly associated with downstream counts at NPE-2 during the fall (r = 1.00, P = 0.0).

## Turbine Operation Evaluation

Sequences of turbines operating for more than 5% of the time, and the number of hours in which they were in operation, varied between seasonal time periods (Figure 7). During the spring and summer periods, mean hourly individual turbine discharge ranged between 13.9 kcfs (Unit 2) and 16.0 kcfs (Unit 6). Mean hourly kcfs per turbine unit was lower during the fall period, ranging from 12.3 (Unit 3) to 14.1 (Unit 1).

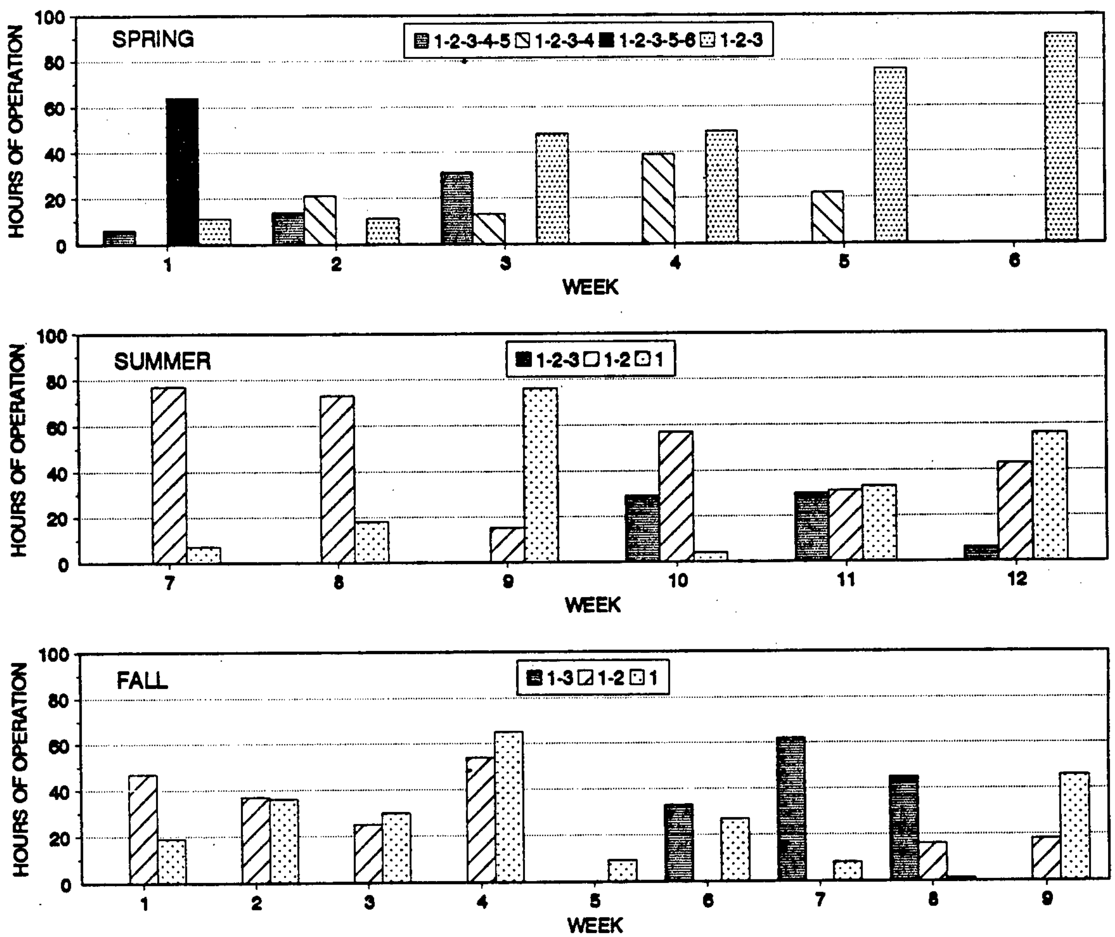


Figure 7. Hours of turbine operations for weeks during the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

Patterns of relative and absolute upstream and downstream counts tended to change as turbines were brought on- or off-line during seasonal periods (Tables 6, 7, and 8; **APPENDIX C**). During the spring period, relative upstream and downstream counts at SSE were slightly higher when Units 5 and 6 were not operating (Table 6). Relative upstream and downstream counts at NSE increased slightly when Turbine 6 was in operation. Relative upstream counts at FOGs were usually higher when the most northerly operating turbine was in close proximity. Relative upstream and downstream counts varied among the NPEs, but were usually lower when Turbines 1 through 3 were operating.

During the summer weeks, relative upstream counts were higher at SSE, FOG-1, and FOG-4 and lower at NSE when Turbines 1 and 2 were in operation (versus Turbine 1-3 or 1; Table 7). There was no consistent trend in relative passage estimates at the NPEs among turbine operations for the summer period.

During the fall period, relative upstream and downstream counts tended to be higher at SSE and lower at NSE, when only Unit 1 was operating (versus Units 1 and 2 or Units 1, 3; Table 8). No consistent trend was evident for relative upstream and downstream counts at the FOGs and NPEs in relation to turbine operation.

The averages in relative upstream and downstream counts between extremes in turbine operations were significantly different at some fishway entrances or entrance groupings within seasonal time periods (Table 9). Relative upstream counts at the combined FOGs increased significantly during the spring ($Z$ = 2.98, $P$ = 0.0029) and summer ($Z$ = 2.24, $P$ = 0.0248) as additional units came on-line. A significant increase in the average of relative upstream counts also occurred at the combined NPEs in the fall ($Z$ = 4.77, $P$ = 0.0001) with an increase in turbines operating. The average in relative downstream counts decreased significantly at SSE (spring; $Z$ = -3.02, $P$ = 0.0025) and increased significantly at NSE (spring; $Z$ = 2.89, $P$ = 0.0038) and combined FOGs (summer; $Z$ = 2.02, $P$ = 0.043) as additional units were brought on-line.

Table 6. Relative median, minimum, maximum, and standard deviation values for total daily upstream and downstream fish counts at fishway entrances under various turbine operations during the <u>spring</u> period (29 April - 10 June) at Lower Granite Dam, Snake River, 1992. Data is from electronic tunnel counts.

| | | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Percent | | | | Percent | | | |
| Entrance, units operating | *N* (days) | Median | Min | Max | SD | Median | Min | Max | SD |
| SSE, | | | | | | | | | |
| 1-5 | 7 | 28.60 | 12 | 34 | 7.62 | 27.78 | 18 | 38 | 7.57 |
| 1-3,5,6 | 5 | 26.07 | 21 | 32 | 4.78 | 32.60 | 14 | 40 | 10.42 |
| 1-4 | 16 | 32.70 | 3 | 62 | 14.22 | 39.22 | 5 | 72 | 18.60 |
| 1-3 | 27 | 31.54 | 14 | 59 | 9.50 | 58.71 | 14 | 73 | 16.20 |
| FOG-1, | | | | | | | | | |
| 1-5 | 7 | 2.63 | 1 | 21 | 7.24 | 0.82 | 0 | 2 | 0.76 |
| 1-3,5,6 | 5 | 3.96 | 2 | 6 | 1.45 | 1.18 | 1 | 2 | 0.42 |
| 1-4 | 16 | 2.26 | 0 | 18 | 4.38 | 0.98 | 0 | 3 | 0.86 |
| 1-3 | 27 | 2.32 | 1 | 43 | 11.41 | 1.38 | 0 | 11 | 1.96 |
| FOG-4, | | | | | | | | | |
| 1-5 | 7 | 3.90 | 2 | 17 | 5.08 | 0.36 | 0 | 1 | 0.30 |
| 1-3,5,6 | 5 | 3.91 | 1 | 11 | 3.95 | 0.85 | 1 | 1 | 0.32 |
| 1-4 | 16 | 3.36 | 0 | 10 | 3.03 | 0.18 | 0 | 2 | 0.90 |
| 1-3 | 27 | 6.26 | 0 | 19 | 4.31 | 0.68 | 0 | 3 | 0.70 |
| FOG-7, | | | | | | | | | |
| 1-5 | 7 | 15.15 | 10 | 28 | 6.55 | 0.68 | 0 | 3 | 0.89 |
| 1-3,5,6 | 5 | 0.89 | 1 | 3 | 1.09 | 0.43 | 0 | 2 | 0.63 |
| 1-4 | 16 | 9.79 | 2 | 27 | 7.42 | 0.53 | 0 | 4 | 1.19 |
| 1-3 | 27 | 4.76 | 1 | 15 | 3.56 | 0.77 | 0 | 6 | 1.15 |
| FOG-10, | | | | | | | | | |
| 1-5 | 7 | 5.96 | 3 | 9 | 2.21 | 0.69 | 0 | 3 | 0.84 |
| 1-3,5,6 | 5 | 7.85 | 5 | 12 | 2.70 | 0.59 | 1 | 2 | 0.52 |
| 1-4 | 16 | 4.48 | 0 | 13 | 3.58 | 0.37 | 0 | 2 | 0.71 |
| 1-3 | 27 | 0.97 | 0 | 13 | 2.73 | 0.43 | 0 | 4 | 0.81 |
| NPE-1, | | | | | | | | | |
| 1-5 | 4 | 0.99 | 0 | 2 | 0.75 | 10.84 | 3 | 30 | 12.03 |
| 1-3,5,6 | 5 | 4.29 | 3 | 6 | 1.52 | 11.67 | 6 | 17 | 4.39 |
| 1-4 | 12 | 1.42 | 0 | 6 | 1.85 | 8.68 | 3 | 17 | 4.61 |
| 1-3 | 14 | 1.42 | 0 | 6 | 1.79 | 5.32 | 2 | 14 | 3.45 |
| NPE-2, | | | | | | | | | |
| 1-5 | 4 | 3.10 | 0 | 6 | 2.78 | 27.77 | 8 | 35 | 11.59 |
| 1-3,5,6 | 5 | 2.62 | 1 | 10 | 3.69 | 12.53 | 10 | 21 | 4.77 |
| 1-4 | 7 | 4.38 | 1 | 14 | 5.12 | 11.62 | 7 | 33 | 10.91 |

Table 6. Continued.

| Entrance, units operating | N (days) | Upstream counts Percent Median | Min | Max | SD | Downstream counts Percent Median | Min | Max | SD |
|---|---|---|---|---|---|---|---|---|---|
| 1-3 | 21 | 2.35 | 0 | 14 | 3.53 | 10.15 | 4 | 35 | 8.15 |
| NPE-3, | | | | | | | | | |
| 1-5 | 6 | 1.38 | 1 | 11 | 3.99 | 2.81 | 0 | 17 | 6.44 |
| 1-4 | 13 | 1.64 | 0 | 14 | 4.70 | 1.64 | 0 | 21 | 6.67 |
| 1-3 | 19 | 1.24 | 0 | 5 | 1.48 | 0.94 | 0 | 3 | 0.88 |
| NSE, | | | | | | | | | |
| 1-5 | 7 | 30.96 | 19 | 54 | 10.61 | 36.77 | 23 | 66 | 16.88 |
| 1-3,5,6 | 5 | 49.58 | 23 | 63 | 14.61 | 41.17 | 29 | 61 | 11.80 |
| 1-4 | 16 | 31.81 | 10 | 49 | 9.77 | 30.54 | 7 | 49 | 12.52 |
| 1-3 | 27 | 36.75 | 6 | 58 | 14.18 | 21.28 | 0 | 62 | 12.20 |

Table 7. Relative median, minimum, maximum, and standard deviation values for total daily upstream and downstream fish counts at fishway entrances under various turbine operations during weeks of the summer period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992. Data is from video observations of adult salmonids.

| Week, entrance, units operating | *N* (days) | Upstream counts: Percent Median | Min | Max | SD | Downstream counts: Percent Median | Min | Max | SD |
|---|---|---|---|---|---|---|---|---|---|
| Week 7, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-2 | 6 | 16.13 | 8 | 31 | 8.69 | 16.97 | 6 | 29 | 9.57 |
| 1 | 3 | 0.00 | 0 | 23 | 13.32 | 0.00 | 0 | 4 | 2.42 |
| FOG-7 | | | | | | | | | |
| 1-2 | 6 | 0.33 | 0 | 3 | 1.21 | 0.18 | 0 | 4 | 1.44 |
| 1 | 3 | 0.00 | 0 | 7 | 4.22 | 0.00 | 0 | 0 | 0.00 |
| NPE-1 | | | | | | | | | |
| 1-2 | 6 | 0.22 | 0 | 2 | 0.86 | 0.92 | 0 | 5 | 1.99 |
| 1 | 3 | 0.00 | 0 | 0 | 0.00 | 0.00 | 0 | 6 | 3.40 |
| NPE-2 | | | | | | | | | |
| 1-2 | 6 | 1.09 | 0 | 3 | 1.00 | 65.16 | 41 | 85 | 14.91 |
| 1 | 3 | 0.00 | 0 | 0 | 0.00 | 95.81 | 94 | 100 | 3.03 |
| NSE | | | | | | | | | |
| 1-2 | 6 | 81.67 | 66 | 91 | 9.16 | 13.41 | 7 | 28 | 8.62 |
| 1 | 3 | 92.68 | 77 | 100 | 11.79 | 0.00 | 0 | 0 | 0.00 |
| Week 8, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-2 | 6 | 16.52 | 5 | 25 | 7.23 | 2.66 | 0 | 16 | 6.12 |
| 1 | 2 | 7.66 | 2 | 13 | 8.25 | 12.73 | 11 | 14 | 1.98 |
| FOG-7 | | | | | | | | | |
| 1-2 | 6 | 0.55 | 0 | 4 | 1.64 | 0.00 | 0 | 1 | 0.44 |
| 1 | 2 | 0.00 | 0 | 0 | 0.00 | 0.32 | 0 | 1 | 0.46 |
| NPE-1 | | | | | | | | | |
| 1-2 | 6 | 0.69 | 0 | 2 | 0.93 | 12.23 | 4 | 31 | 11.26 |
| 1 | 2 | 0.00 | 0 | 0 | 0.00 | 5.20 | 4 | 6 | 1.78 |
| NSE | | | | | | | | | |
| 1-2 | 6 | 81.10 | 75 | 95 | 7.36 | 79.07 | 69 | 92 | 9.40 |
| 1 | 2 | 92.34 | 87 | 98 | 8.25 | 81.75 | 79 | 85 | 4.21 |
| Week 9, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-2 | 2 | 39.91 | 36 | 44 | 5.88 | 18.93 | 18 | 19 | 0.71 |
| 1 | 7 | 26.32 | 0 | 48 | 17.02 | 18.26 | 12 | 31 | 8.03 |
| FOG-1 | | | | | | | | | |
| 1-2 | 2 | 7.34 | 7 | 8 | 0.51 | 0.55 | 0 | 1 | 0.78 |
| 1 | 7 | 0.18 | 0 | 1 | 0.29 | 0.47 | 0 | 6 | 2.15 |

Table 7. Continued.

| Week, entrance, units operating | N (days) | Upstream counts Median | Percent Min | Percent Max | SD | Downstream counts Median | Percent Min | Percent Max | SD |
|---|---|---|---|---|---|---|---|---|---|
| 1-2 | 2 | 13.85 | 11 | 17 | 4.12 | 75.80 | 70 | 82 | 8.17 |
| Week 9, | | | | | | | | | |
| NPE-2 | | | | | | | | | |
| 1 | 7 | 6.82 | 4 | 43 | 13.82 | 73.00 | 59 | 77 | 7.26 |
| NSE | | | | | | | | | |
| 1-2 | 2 | 38.89 | 37 | 41 | 2.28 | 4.72 | 0 | 9 | 6.68 |
| 1 | 7 | 59.46 | 48 | 73 | 10.22 | 8.34 | 3 | 12 | 3.29 |
| Week 10, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-3 | 2 | 39.24 | 31 | 48 | 12.20 | 34.77 | 31 | 38 | 5.23 |
| 1-2 | 4 | 50.17 | 46 | 53 | 3.06 | 30.92 | 22 | 61 | 17.32 |
| FOG-1 | | | | | | | | | |
| 1-3 | 2 | 3.76 | 2 | 6 | 3.15 | 7.02 | 4 | 10 | 4.58 |
| 1-2 | 4 | 4.36 | 2 | 9 | 2.95 | 2.55 | 1 | 5 | 1.61 |
| NPE-1 | | | | | | | | | |
| 1-3 | 2 | 0.52 | 0 | 1 | 0.74 | 42.30 | 26 | 59 | 23.56 |
| 1-2 | 4 | 0.63 | 0 | 1 | 0.34 | 59.05 | 27 | 75 | 20.61 |
| NSE | | | | | | | | | |
| 1-3 | 2 | 56.49 | 45 | 68 | 16.08 | 15.91 | 6 | 26 | 13.76 |
| 1-2 | 4 | 44.06 | 43 | 48 | 2.32 | 6.43 | 2 | 10 | 3.36 |
| Week 11, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-3 | 3 | 3.34 | 3 | 65 | 35.72 | 16.02 | 9 | 79 | 38.35 |
| 1-2 | 4 | 26.03 | 0 | 69 | 28.57 | 14.52 | 4 | 66 | 27.91 |
| 1 | 4 | 23.29 | 0 | 65 | 27.63 | 10.46 | 3 | 21 | 8.33 |
| FOG-4 | | | | | | | | | |
| 1-3 | 3 | 34.78 | 28 | 53 | 13.28 | 1.60 | 0 | 6 | 2.94 |
| 1-2 | 4 | 59.08 | 4 | 66 | 28.76 | 1.03 | 0 | 8 | 3.49 |
| 1 | 4 | 20.92 | 0 | 100 | 44.19 | 0.75 | 0 | 4 | 1.76 |
| NPE-1 | | | | | | | | | |
| 1-3 | 2 | 0.67 | 0 | 1 | 0.95 | 27.44 | 23 | 32 | 6.58 |
| 1-2 | 4 | 0.76 | 0 | 4 | 1.83 | 20.93 | 8 | 46 | 15.88 |
| 1 | 4 | 0.00 | 0 | 39 | 19.35 | 18.78 | 12 | 20 | 3.32 |
| NPE-2 | | | | | | | | | |
| 1-3 | 3 | 0.00 | 0 | 0 | 0.00 | 21.05 | 15 | 29 | 6.89 |
| 1-2 | 4 | 0.00 | 0 | 4 | 1.94 | 44.19 | 15 | 66 | 25.36 |
| 1 | 4 | 0.00 | 0 | 0 | 0.00 | 60.60 | 48 | 78 | 12.47 |
| NSE | | | | | | | | | |
| 1-3 | 3 | 43.21 | 0 | 68 | 34.22 | 21.39 | 0 | 47 | 23.45 |
| 1-2 | 4 | 17.15 | 6 | 40 | 16.13 | 6.84 | 0 | 13 | 5.78 |

Table 7. Continued.

| Week, entrance, units operating | N (days) | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Percent | | | | Percent | | | |
| | | Median | Min | Max | SD | Median | Min | Max | SD |
| 1 | 4 | 21.72 | 0 | 64 | 28.17 | 10.47 | 0 | 12 | 5.62 |
| Week 12, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-2 | 3 | 53.42 | 47 | 64 | 8.62 | 29.68 | 20 | 51 | 15.57 |
| 1 | 4 | 17.58 | 9 | 52 | 20.08 | 22.35 | 9 | 31 | 9.19 |
| FOG-4 | | | | | | | | | |
| 1-2 | 3 | 25.02 | 16 | 25 | 5.55 | 1.81 | 1 | 5 | 2.24 |
| 1 | 4 | 7.76 | 0 | 11 | 4.76 | 0.66 | 0 | 2 | 1.03 |
| NPE-2 | | | | | | | | | |
| 1-2 | 3 | 0.00 | 0 | 3 | 1.61 | 48.44 | 45 | 48 | 1.85 |
| NPE-2 | | | | | | | | | |
| 1 | 4 | 1.28 | 0 | 22 | 10.55 | 63.55 | 55 | 86 | 13.10 |
| NSE | | | | | | | | | |
| 1-2 | 3 | 25.02 | 11 | 31 | 10.55 | 16.84 | 0 | 33 | 16.29 |
| 1 | 4 | 60.78 | 41 | 90 | 20.14 | 12.40 | 6 | 14 | 3.79 |

Table 8. Relative median, minimum, maximum, and standard deviation values for total daily upstream and downstream fish counts at fishway entrances under various turbine operations during weeks of the fall period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992. Data is from video observations of adult salmonids.

| Week, entrance, units operating | *N* (days) | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Percent | | | | Percent | | | |
| | | Median | Min | Max | SD | Median | Min | Max | SD |
| Week 1, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-2 | 7 | 28.30 | 18 | 67 | 16.69 | 10.00 | 5 | 28 | 8.32 |
| 1 | 6 | 24.47 | 17 | 38 | 7.76 | 11.60 | 7 | 23 | 5.33 |
| FOG-10 | | | | | | | | | |
| 1-2 | 7 | 9.23 | 4 | 16 | 4.22 | 2.82 | 2 | 9 | 2.68 |
| 1 | 6 | 8.06 | 3 | 26 | 8.11 | 1.99 | 0 | 12 | 4.47 |
| NPE-1 | | | | | | | | | |
| 1-2 | 7 | 1.61 | 0 | 3 | 1.29 | 12.82 | 0 | 30 | 8.91 |
| 1 | 6 | 0.00 | 0 | 19 | 7.40 | 28.40 | 5 | 47 | 14.91 |
| NPE-2 | | | | | | | | | |
| 1-2 | 7 | 5.66 | 0 | 18 | 6.76 | 35.77 | 16 | 56 | 15.08 |
| 1 | 6 | 5.54 | 0 | 17 | 6.07 | 28.94 | 12 | 47 | 11.60 |
| NSE | | | | | | | | | |
| 1-2 | 7 | 56.60 | 21 | 64 | 16.75 | 28.56 | 12 | 59 | 17.53 |
| 1 | 6 | 54.11 | 43 | 63 | 7.52 | 28.50 | 11 | 50 | 12.57 |
| Week 2, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-2 | 4 | 50.85 | 48 | 64 | 7.04 | 11.97 | 6 | 17 | 4.39 |
| 1 | 6 | 62.98 | 47 | 79 | 12.57 | 8.09 | 3 | 20 | 6.77 |
| FOG-10 | | | | | | | | | |
| 1-2 | 4 | 7.05 | 2 | 9 | 3.25 | 0.83 | 1 | 1 | 0.43 |
| 1 | 6 | 2.17 | 1 | 9 | 3.28 | 0.77 | 0 | 3 | 1.10 |
| NPE-1 | | | | | | | | | |
| 1-2 | 2 | 1.31 | 0 | 2 | 1.31 | 28.45 | 11 | 46 | 24.88 |
| 1 | 4 | 0.25 | 0 | 5 | 2.44 | 33.19 | 26 | 57 | 14.57 |
| NSE | | | | | | | | | |
| 1-2 | 4 | 41.91 | 32 | 42 | 4.99 | 78.98 | 47 | 87 | 18.78 |
| 1 | 6 | 32.69 | 15 | 53 | 15.47 | 59.81 | 40 | 91 | 18.26 |
| Week 3, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-2 | 4 | 47.77 | 42 | 52 | 4.37 | 22.08 | 14 | 31 | 8.92 |
| 1 | 6 | 45.26 | 11 | 68 | 19.16 | 23.09 | 16 | 32 | 5.52 |
| FOG-1 | | | | | | | | | |
| 1-2 | 2 | 26.53 | 20 | 33 | 9.22 | 3.11 | 3 | 3 | 0.25 |
| 1 | 3 | 14.66 | 2 | 25 | 11.76 | 3.05 | 1 | 5 | 2.03 |

Table 8. Continued.

| Week, entrance, units operating | N (days) | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Percent | | | | Percent | | | |
| | | Median | Min | Max | SD | Median | Min | Max | SD |
| FOG-10 | | | | | | | | | |
| 1-2 | 2 | 2.16 | 2 | 3 | 0.56 | 0.46 | 0 | 1 | 0.06 |
| 1 | 4 | 1.06 | 1 | 1 | 0.21 | 0.44 | 0 | 1 | 0.21 |
| NPE-2 | | | | | | | | | |
| 1-2 | 4 | 1.78 | 1 | 3 | 1.14 | 34.00 | 25 | 49 | 12.10 |
| 1 | 6 | 2.18 | 1 | 4 | 1.21 | 28.98 | 5 | 52 | 18.13 |
| NSE | | | | | | | | | |
| 1-2 | 4 | 36.29 | 20 | 53 | 14.77 | 41.75 | 36 | 43 | 3.49 |
| 1 | 6 | 48.31 | 27 | 63 | 13.31 | 50.30 | 28 | 58 | 13.26 |
| Week 4, SSE | | | | | | | | | |
| 1-2 | 6 | 35.20 | 22 | 58 | 13.33 | 24.10 | 21 | 28 | 2.65 |
| 1 | 4 | 51.18 | 35 | 69 | 16.70 | 28.47 | 22 | 38 | 6.72 |
| FOG-1 | | | | | | | | | |
| 1-2 | 6 | 19.78 | 5 | 40 | 14.74 | 3.06 | 1 | 4 | 1.11 |
| 1 | 4 | 15.78 | 3 | 17 | 6.63 | 3.29 | 1 | 7 | 2.44 |
| NPE-1 | | | | | | | | | |
| 1-2 | 6 | 0.50 | 0 | 1 | 0.36 | 32.68 | 24 | 39 | 6.48 |
| 1 | 4 | 1.77 | 0 | 4 | 1.89 | 46.79 | 36 | 51 | 6.71 |
| NSE | | | | | | | | | |
| 1-2 | 6 | 41.19 | 33 | 47 | 5.56 | 39.49 | 32 | 48 | 6.12 |
| 1 | 4 | 38.43 | 12 | 45 | 15.37 | 23.03 | 15 | 26 | 4.79 |
| Week 5, SSE | | | | | | | | | |
| 1 | 7 | 67.63 | 60 | 76 | 5.00 | 66.23 | 56 | 73 | 5.75 |
| FOG-4 | | | | | | | | | |
| 1 | 7 | 2.58 | 1 | 10 | 3.93 | 1.70 | 0 | 4 | 1.47 |
| NPE-1 | | | | | | | | | |
| 1 | 6 | 0.00 | 0 | 1 | 0.19 | 20.77 | 11 | 28 | 6.91 |
| NSE | | | | | | | | | |
| 1 | 7 | 26.50 | 20 | 37 | 5.51 | 10.97 | 5 | 31 | 10.62 |
| Week 6, SSE | | | | | | | | | |
| 1,3 | 5 | 41.30 | 38 | 46 | 2.82 | 44.00 | 20 | 51 | 12.33 |
| 1 | 5 | 80.87 | 53 | 89 | 13.81 | 56.25 | 32 | 80 | 18.08 |
| FOG-4 | | | | | | | | | |
| 1,3 | 5 | 1.37 | 1 | 7 | 2.57 | 1.10 | 0 | 2 | 0.85 |
| 1 | 5 | 1.82 | 0 | 4 | 1.70 | 1.38 | 0 | 3 | 1.43 |
| NPE-2 | | | | | | | | | |
| 1,3 | 5 | 2.22 | 0 | 10 | 4.19 | 35.58 | 24 | 42 | 7.58 |

Table 8. Continued.

| Week, entrance, units operating | N (days) | Upstream counts: Percent Median | Min | Max | SD | Downstream counts: Percent Median | Min | Max | SD |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 2.38 | 0 | 6 | 2.59 | 16.22 | 8 | 44 | 14.18 |
| NSE | | | | | | | | | |
| 1,3 | 5 | 55.17 | 43 | 62 | 8.28 | 26.07 | 12 | 39 | 10.06 |
| 1 | 6 | 14.24 | 11 | 40 | 12.25 | 21.23 | 5 | 35 | 11.19 |
| Week 7, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1,3 | 7 | 51.94 | 49 | 71 | 8.47 | 24.57 | 16 | 42 | 9.20 |
| FOG-7 | | | | | | | | | |
| 1,3 | 7 | 0.93 | 0 | 2 | 0.74 | 0.28 | 0 | 1 | 0.21 |
| NPE-1 | | | | | | | | | |
| 1,3 | 7 | 9.13 | 7 | 13 | 2.35 | 19.11 | 8 | 27 | 7.60 |
| NPE-2 | | | | | | | | | |
| 1,3 | 7 | 4.46 | 1 | 11 | 3.08 | 22.66 | 8 | 34 | 8.67 |
| NSE | | | | | | | | | |
| 1,3 | 7 | 29.74 | 13 | 37 | 7.54 | 32.93 | 11 | 59 | 17.45 |
| Week 8, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1,3 | 5 | 72.28 | 53 | 84 | 11.73 | 50.88 | 43 | 61 | 7.46 |
| 1-2 | 3 | 75.86 | 62 | 87 | 12.62 | 47.76 | 47 | 61 | 7.79 |
| FOG-7 | | | | | | | | | |
| 1,3 | 5 | 0.65 | 0 | 2 | 0.96 | 0.48 | 0 | 1 | 0.55 |
| 1-2 | 3 | 2.91 | 2 | 5 | 1.88 | 0.00 | 3 | 1 | 0.86 |
| NPE-1 | | | | | | | | | |
| 1,3 | 5 | 8.03 | 4 | 10 | 2.25 | 29.87 | 27 | 37 | 4.28 |
| 1-2 | 3 | 3.10 | 10 | 6 | 2.91 | 26.87 | 18 | 28 | 5.17 |
| NSE | | | | | | | | | |
| 1,3 | 5 | 15.84 | 5 | 39 | 12.82 | 19.19 | 12 | 20 | 3.74 |
| 1-2 | 3 | 19.31 | 4 | 32 | 14.29 | 23.88 | 11 | 34 | 11.53 |
| Week 9, | | | | | | | | | |
| SSE | | | | | | | | | |
| 1-2 | 3 | 93.75 | 74 | 97 | 12.14 | 84.27 | 12 | 90 | 43.63 |
| 1 | 6 | 92.05 | 80 | 94 | 5.38 | 72.51 | 70 | 82 | 4.56 |
| FOG-7 | | | | | | | | | |
| 1-2 | 3 | 0.00 | 0 | 0 | 0.00 | 2.00 | 2 | 2 | 0.35 |
| 1 | 6 | 0.00 | 0 | 1 | 0.16 | 0.00 | 0 | 0 | 0.00 |
| NPE-2 | | | | | | | | | |
| 1-2 | 3 | 0.00 | 0 | 6 | 3.58 | 7.14 | 5 | 54 | 27.68 |
| 1 | 6 | 0.78 | 0 | 5 | 1.74 | 16.35 | 12 | 19 | 2.66 |

Table 8. Continued.

| Week, entrance, units operating | N (days) | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Percent | | | | Percent | | | |
| | | Median | Min | Max | SD | Median | Min | Max | SD |
| NSE | | | | | | | | | |
| 1-2 | 3 | 6.25 | 3 | 19 | 8.60 | 9.00 | 0 | 32 | 16.50 |
| 1 | 6 | 6.63 | 5 | 20 | 5.88 | 9.95 | 6 | 15 | 3.83 |

Table 9. Results of the Wilcoxon two-sample test of daily upstream and downstream fish counts at fishway entrances versus turbine operations during the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

| Season, entry, units operating | *N* (days) | Mean score | | *Z* - value | | *P* - value | |
|---|---|---|---|---|---|---|---|
| | | Up | Dn | Up | Dn | Up | Dn |
| Spring[a], | | | | | | | |
| SSE | | | | | | | |
| 1-2-3 | 27 | 18.85 | 20.15 | -1.53 | -3.02 | 0.1252 | 0.0025 |
| 1-2-3-4-5 | 7 | 12.29 | 7.29 | | | | |
| FOGs | | | | | | | |
| 1-2-3 | 27 | 14.89 | 18.55 | 2.98 | -1.19 | 0.0029 | 0.2330 |
| 1-2-3-4-5 | 7 | 27.57 | 13.43 | | | | |
| NPEs | | | | | | | |
| 1-2-3 | 27 | 17.17 | 15.78 | 0.36 | 1.96 | 0.7173 | 0.0501 |
| 1-2-3-4-5 | 7 | 18.79 | 24.14 | | | | |
| NSE | | | | | | | |
| 1-2-3 | 27 | 18.15 | 12.35 | -0.72 | 2.89 | 0.4690 | 0.0038 |
| 1-2-3-4-5 | 7 | 15.00 | 15.60 | | | | |
| Summer[b], | | | | | | | |
| SSE | | | | | | | |
| 1 | 20 | 12.35 | 11.65 | 0.85 | 1.80 | 0.3949 | 0.0718 |
| 1-2-3 | 5 | 15.60 | 18.40 | | | | |
| FOGs | | | | | | | |
| 1 | 20 | 11.35 | 11.55 | 2.24 | 2.02 | 0.0248 | 0.0430 |
| 1-2-3 | 5 | 19.60 | 18.80 | | | | |
| NPEs | | | | | | | |
| 1 | 27 | 18.17 | 18.67 | -0.87 | -1.32 | 0.3828 | 0.1867 |
| 1-2-3 | 7 | 14.93 | 13.00 | | | | |
| NSE | | | | | | | |
| 1 | 20 | 13.88 | 12.35 | -1.16 | 0.85 | 0.2480 | 0.3939 |
| 1-2-3 | 5 | 9.50 | 15.60 | | | | |
| Fall[b], | | | | | | | |
| SSE | | | | | | | |
| 1 | 43 | 31.79 | 30.97 | -0.90 | -0.33 | 0.3669 | 0.7428 |
| 1-3 | 17 | 27.24 | 29.29 | | | | |

Table 9. Continued.

| Season, entry, units operating | N (days) | Mean score | | Z - value | | P - value | |
|---|---|---|---|---|---|---|---|
| | | Up | Dn | Up | Dn | Up | Dn |
| FOGs | | | | | | | |
| 1 | 43 | 32.77 | 33.23 | -1.59 | -1.93 | 0.1111 | 0.0531 |
| 1,3 | 17 | 24.76 | 23.59 | | | | |
| NPEs | | | | | | | |
| 1 | 48 | 28.24 | 35.54 | 4.77 | 0.54 | 0.0001 | 0.5868 |
| 1,3 | 24 | 53.02 | 38.42 | | | | |
| NSE | | | | | | | |
| 1 | 43 | 29.98 | 30.42 | 0.36 | 0.05 | 0.7182 | 0.9607 |
| 1-3 | 17 | 31.82 | 30.71 | | | | |

[a] *Passage counts calculated from electronic tunnel data.*
[b] *Passage counts calculated from video camera data.*

## North Powerhouse Entrance Evaluation

Upstream and downstream counts at NPE-2 were usually highest when in combination with NPE-1 or NPE-3 during the spring (Table 10). Within these same combinations, down counts at NPE-2 exceeded up counts by 223% and 491%, respectively. Spring upstream counts were improved at NPE-3 during the 1&3 combination; down counts at NPE-3 varied little with combination changes. During the summer and fall periods, video-imaged down counts continued to be higher at NPE-2 than at NPE-1. When in combination with NPE-3 during all seasons, down counts at NPE-1 and NPE-2 were always higher than when in combination with each other. The NPE combination that tended to produce the highest combined down count during spring and summer was 2&3; the 1&3 NPE combination probably would have been highest in the fall (NPE-3 was not video monitored in the summer and fall).

In the spring, the average down count at NPE-2 was significantly greater ($F = 7.27$, $P = 0.0116$) when combined with NPE-3 than with NPE-1 (Table 11). In the summer, the average down count at NPE-1 was significantly greater ($F = 27.73$, $P = 0.0001$) when combined with NPE-3 than with NPE-2. The average up count at NPE-2 was significantly greater ($F = 13.37$, $P = 0.0012$) when combined with NPE-3 than with NPE-1. In the fall, the average upstream count at NPE-1 was significantly greater ($F = 6.14$, $P = 0.0182$) when combined with NPE-2 than with NPE-3. A significant block effect was not evident indicating that a block experimental design may not have been necessary.

Table 10. Median, minimum, maximum, and standard deviation values for total daily upstream and downstream fish counts at north powerhouse fishway entrances during the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

| Season, comb., entrance | *N* (days) | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Median | Min | Max | SD | Median | Min | Max | SD |
| Spring[a], | | | | | | | | | |
| NPE-1 & 2 | | | | | | | | | |
| NPE-1 | 16 | 9.50 | 5 | 204 | 59.11 | 70.50 | 15 | 243 | 74.60 |
| NPE-2 | 16 | 58.17 | 2 | 196 | 69.42 | 188.00 | 19 | 301 | 96.54 |
| NPE-1 & 3 | | | | | | | | | |
| NPE-1 | 16 | 34.00 | 8 | 157 | 37.23 | 104.00 | 33 | 423 | 112.08 |
| NPE-3 | 16 | 39.00 | 0 | 258 | 74.57 | 18.00 | 0 | 234 | 66.77 |
| NPE-2 & 3 | | | | | | | | | |
| NPE-2 | 16 | 46.00 | 7 | 155 | 42.93 | 272.00 | 51 | 426 | 119.06 |
| NPE-3 | 16 | 21.00 | 0 | 105 | 26.93 | 13.50 | 0 | 102 | 26.10 |
| Summer[b], | | | | | | | | | |
| NPE-1 & 2 | | | | | | | | | |
| NPE-1 | 13 | 2.00 | 0 | 4 | 1.66 | 12.00 | 0 | 62 | 20.17 |
| NPE-2 | 13 | 0.00 | 0 | 12 | 3.41 | 81.13 | 8 | 225 | 69.95 |
| NPE-1 & 3 | | | | | | | | | |
| NPE-1 | 12 | 2.00 | 0 | 4 | 1.80 | 33.18 | 10 | 250 | 87.17 |
| NPE-2 & 3 | | | | | | | | | |
| NPE-2 | 14 | 10.00 | 0 | 77 | 26.30 | 141.03 | 26 | 1190 | 466.00 |
| Fall[b], | | | | | | | | | |
| NPE-1 & 2 | | | | | | | | | |
| NPE-1 | 14 | 34.50 | 0 | 135 | 46.92 | 75.00 | 12 | 450 | 134.86 |
| NPE-2 | 14 | 22.50 | 0 | 93 | 23.84 | 130.50 | 51 | 408 | 111.03 |
| NPE-1 & 3 | | | | | | | | | |
| NPE-1 | 25 | 6.00 | 0 | 108 | 22.30 | 211.94 | 18 | 2313 | 557.30 |
| NPE-2 & 3 | | | | | | | | | |
| NPE-2 | 19 | 12.00 | 0 | 99 | 32.99 | 132.00 | 15 | 1752 | 531.11 |

[a] *Passage counts calculated from electronic tunnel data.*
[b] *Passage counts calculated from video camera data.*

Table 11. Results from analysis of variance of ranked daily upstream and downstream fish counts at NPEs under combinations of two open north powerhouse entrances during the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

| Season entrance, NPE comb. | *N* (days) | Upstream counts Median | F-value | *P* | Downstream counts Median | F-value | *P* |
|---|---|---|---|---|---|---|---|
| Spring[a], | | | | | | | |
| NPE-1 | | | | | | | |
| 1 & 2 | 16 | 49.50 | 0.66 | 0.4228 | 70.50 | 2.43 | 0.1299 |
| 1 & 3 | 16 | 34.00 | | | 104.00 | | |
| NPE-2 | | | | | | | |
| 1 & 2 | 16 | 58.17 | 0.07 | 0.7997 | 188.00 | 7.27 | 0.0116 |
| 2 & 3 | 16 | 46.00 | | | 272.00 | | |
| NPE-3 | | | | | | | |
| 1 & 3 | 12 | 39.00 | 2.45 | 0.1281 | 18.00 | 1.09 | 0.3050 |
| 2 & 3 | 12 | 21.00 | | | 13.50 | | |
| Summer[b], | | | | | | | |
| NPE-1 | | | | | | | |
| 1 & 2 | 13 | 2.00 | 0.96 | 0.3371 | 12.00 | 27.73 | 0.0001 |
| 1 & 3 | 12 | 2.00 | | | 33.18 | | |
| NPE-2 | | | | | | | |
| 1 & 2 | 13 | 1.80 | 13.37 | 0.0012 | 81.13 | 2.63 | 0.1177 |
| 2 & 3 | 14 | 20.92 | | | 141.03 | | |
| Fall[b], | | | | | | | |
| NPE-1 | | | | | | | |
| 1 & 2 | 14 | 34.50 | 6.14 | 0.0182 | 75.00 | 1.02 | 0.3193 |
| 1 & 3 | 25 | 6.00 | | | 211.94 | | |
| NPE-2 | | | | | | | |
| 1 & 2 | 14 | 22.50 | 1.08 | 0.3070 | 130.50 | 0.05 | 0.8319 |
| 2 & 3 | 19 | 12.00 | | | 132.00 | | |

[a] *Passage counts calculated from electronic tunnel data.*
[b] *Passage counts calculated from video camera data.*

## DISCUSSION

A number of caveats need to be addressed before discussing the results: (1) much of the information presented pertains to relative up and down counts because absolute estimates are highly influenced by the run size passing the dam; run size varied greatly within and between study periods (**APPENDIX D**); (2) the inability to distinguish fish species in electronic tunnels somewhat confounds the interpretation of results relating to fish passage during the spring period, which is particularly true for NSE and SSE , where non-salmonids are most likely to pass through the collection channel tunnels on a regular basis; and, (3) because of the placement of SSE and NSE tunnel frames within the collection channel and not in the actual entrances, estimates of downstream counts do not represent fallout into the tailrace.

The "fallout fence," placed in the fishway near NPE-1 and NPE-2, was originally designed to reduce fallout at NPE-1 and NPE-2 during spill discharges ranging from 10 kcfs to 60 kcfs (Turner et al. 1983). Researchers hypothesized that fish falling out of NPE-1 and NPE-2 were the result of a large number of fish entering the fishways via the north shore entrance during periods of low to moderate spill. Evaluations were conducted this year under low-flow conditions with no spill; results indicated that the fallout fence was not effective in reducing fallout. Although the fallout fence may have kept fish that entered NPE-3 and NSE from falling out at NPE-1 and NPE-2, it may have corralled fish moving downstream in the collection channel from the south end and guided them out NPE-1 and NPE-2.

It is apparent that fish falling out at these entrances entered the fishway elsewhere because the magnitude of fallout at NPE-1 and NPE-2 greatly exceeded the magnitude of entry. These results are similar to those observed for fallout fence evaluations conducted in 1991 at Little Goose and Lower Granite dams (Knutsen and Knapp 1992). During the summer and fall periods in 1992, the tendency for downstream movement and subsequent fallout at NPEs from the south collection channel was also indicated by the strong correlations between use at SSE and NPE fallout. If fallout is attributable to fish moving down the collection channel and guided out by the fence, then removal of the fence or increased transport velocities along the collection channel may facilitate upstream movement.

The presence of the fence and electronic tunnel equipment, themselves, may also influence use and fallout at NPE-1 and NPE-2. The close proximity of the fallout fence to these entrances may have inhibited entry or may have caused fish that did enter to turn and immediately fall out. Also, because tunnel structures extend into the tailrace at NPE-1 and NPE-2, use may be further obstructed.

Alternatives to the fallout fence, such as fyking, may be necessary to reduce fallout through NPE-1 and NPE-2. However, since entry is minimal at these entrances, we agree with Turner (1983) that it may be better to close one or both of them if it can be accomplished without impeding transport velocities in the collection channel. This might also alleviate water supply needs during periods of low tailwater. However, other entrances should not be opened or modified (as recommended by Turner 1983) unless further testing accompanies the changes. It should be noted that the presence of the fallout fence may have confounded our evaluation of combinations of two north

powerhouse entrances that were open because of its effects on use and fallout at NPE-1 and NPE-2. If the fallout fence is to be modified or removed, we should re-evaluate use and fallout at north powerhouse entrances when various combinations are open.

During 1993, the fallout fence will remain at Little Goose Dam and be removed at Lower Granite Dam. Radio telemetry has been proposed for use at both dams to evaluate entrance use and fallout. Rotations of open NPEs are proposed to continue at both dams during the summer and fall, as was done at Lower Granite Dam in 1992. During the spring, NPE-1 and NPE-2 will remain open during periods of spill and non-spill to evaluate passage with the fallout fence (Little Goose Dam) and without the fallout fence (Lower Granite Dam) in place. Leaving these entrances open during spill may allow assessment of entrance use under high flow conditions.

We are not certain why the fallout index at SSE and NPEs was so much greater this spring than in previous springs. Run size of adult salmonids during the spring was greater this year (15,332) than in 1991 (5,989) or 1981 (13,851). If fish were counted disproportionately by electronic tunnels this year compared to previous years, it may have resulted in an overestimation of the fallout index (see **Report B**). Differential fish behavior or changes in fishway operation among study years could also be contributing factors.

Electronic tunnel counts indicated that entrance fallout was proportional to use for entrances other than NPE-1 and NPE-2 during the spring period. In general, entrances with high use usually had high fallout and those with low use had low fallout. This trend was similar to that reported by Johnson et al. (1979, 1982), Turner et al. (1983, 1984) and Knutsen and Knapp (1992) for previous fish passage research involving electronic impedance tunnels. However, use and fallout during the summer and fall periods, using video cameras, did not reveal a distinct proportional relationship. The most used entrances often had low fallout. Therefore, it is possible that the occurrence of proportional relationships between use and fallout may be more related to inherent problems with electronic tunnel use than to true passage activity at the entrances (*see* **Report B**).

Greater use of the entrances close to the shore (SSE and/or NSE) was consistent with reports from other dams on the Columbia (Johnson et al. 1979, 1982) and Snake (Turner et al. 1983, 1984) rivers. Gordon (1965) noted that migrating salmonids hold close to the river margins. Therefore, as fish approach the dam, the first entrances they encounter are probably the shore entrances. Also, high use through SSE and NSE is probably related to the large volume of discharge, which serves as attractants for fish.

Reasons for low use and fallout rates at FOGs are probably related to their smaller size and lower discharge. Fish migrating through the collection channel are less likely to encounter discharge from an FOG than outflow from larger entrances such as NPEs. Additionally, fish approaching the powerhouse from the tailrace area probably cannot locate FOGs because attraction flows are extremely low in relation to turbine discharges from the powerhouse. Johnson et al. (1982) suggested that FOGs at John Day Dam on the Columbia River may have experienced lower fallout because the impedance tunnels extended into the fishway and blocked potential fallouts.

The current location of open floating orifice gates may be suitable given their relatively low fallout during most periods. However, tests should be conducted to determine if opening other FOGs would be more suitable to fish passage.

Explanations of seasonal variations in entrance use and fallout patterns are confounded by numerous biological, environmental, and operational variables. Species or race-specific differences in fish behavior, changing water conditions, and variable powerhouse operations all contribute to the efficiency of fish passage. Therefore, it is likely that more than one fishway operation scenario may be needed to pass fish in an efficient and timely manner.

During 1992, we attempted to gauge water velocities in the fishway collection channel, but the range of velocities we observed or the precision of our measurements was not sufficient to detect the effects of velocity on fallout. Although tests have been conducted in the past to determine the effects of transport velocities on salmonid passage (Gauley 1966), these tests were conducted under laboratory conditions where fish were not provided with the opportunity to fallout through numerous high velocity entrances.

Collection channel water velocities are regulated by a system of diffusers that distribute the auxiliary water supply and weir gates, which regulate the head differential at most entrances. Collection channel velocities can also be influenced by turbine use (Larry Basham, Fish Passage Center, Portland, Oregon, personal communication), as turbine boils raise water elevations in the tailrace and portions of the collection channel. This creates "humps" that can impede the water velocity. Further experiments should be designed to test a wider range of velocities (1-4 fps) in the fishway and to detect the hydraulic effects of powerhouse operation on fishway conditions.

The effects of water temperature on entrance use were not apparent. Although we observed a wide range of water temperatures, changes in temperature did not correlate well with most entrance activity. This is probably because auxiliary supply water is added to the collection system from the tailrace. As Gordon (1965) reported, fish would only be reluctant to enter a collection system that is warmer than the tailrace; this does not appear to be the case at Lower Granite Dam.

Non-target fish species (e.g. carp, suckers, and shad) comprise a relatively large percentage of the fish population in the adult collection system during certain times of the year (*see* **Report B**). These fishes may affect the migration success of adult salmonids, either directly through impedance of passage, or indirectly through transmission of disease (Memorandum to fish passage consultation attendees of 11/21/88, Jim Ruff, Northwest Power Planning Council, Portland, Oregon). Further research is needed to identify the effects of resident fish species on adult salmonids passing through fishways.

The direct effects of total discharge through the powerhouse may not be as important of a factor affecting entrance use and fallout as the discharge through individual turbines. Individual turbine discharge had some influence on entrance use; operation of only the southernmost turbines tended to

increase passage at the southern entrances and reduce passage at northern entrances. As additional turbines were brought on-line, attraction flows spread across the face of the powerhouse, and fish were generally attracted to the more northerly entrances. The limited number of turbines in operation in the fall did not allow for an effective evaluation of northern entrance use during this seasonal period. It is difficult to adequately assess direct significant effects of changes in turbine use without an experimental block design. Further research should be conducted that tests extremes in turbine use (Unit 1 versus Unit 6) under a randomized block design.

Although turbine operations probably do not have a direct effect on fallout, indirect effects may exist. Possible indirect effects include (1) attracttion to certain entrances that result in increased fallout at other entrances (i.e. use at NSE and SSE results in fallout at NPEs), (2) impedance of passage as fish encounter turbine noise in the collection channel, and (3) as mentioned previously, effects on fishway operations (e.g. velocities, head differentials) caused by adjacent turbine boils.

During 1992, our evaluation of open NPE combinations was limited by our inability to install cameras at NPE-3 and the malfunction of the electronic tunnels at that location. However, passage estimates indicated that NPE-3 did not appear to be an asset or a detriment to fish passage, but fallout was extremely high at NPE-1 and NPE-2. We agree with recommendations to close NPE-1 and NPE-2 during low flows if suitable modifications to the entrances cannot be made. In high flow periods (spill), more testing is needed. If these entrances cannot be closed without negatively impacting fishway flows, then flows should be regulated to provide ideal conditions for those entrances selected to be open. Flow limitations alone should not dictate which entrances are open and which entrances are closed. All entrance modifications or closures should be evaluated prior to re-establishing fishway operating criteria.

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## RECOMMENDATIONS

1) Evaluate use and fallout at NPE-1 and NPE-2 with and without the fallout fence in place and during periods of spill and non-spill to determine fence and spill effects on passage efficiency at these entrances (scheduled for Little Goose Dam and Lower Granite Dam in 1993).

2) Rotate NPE combinations at Little Goose and Lower Granite dams during summer and fall periods to determine the combination that minimizes fallout (scheduled for both projects, 1993).

3) If high fallout and low use persists at NPE-1 and NPE-2 during spill and non-spill conditions, close these entrances and regulate fishway flows to accommodate new conditions.

4) Develop and implement designed tests to determine the effects of discrete turbine operations on fishway entrance use and fallout. Identify hydraulic conditions stemming from various turbine discharge patterns and determine their effect on fishway operation and fish behavior.

5) Conduct tests to evaluate fishway operations over a wide range of conditions. Look specifically at the effects of water velocity on fallout. Current operating criteria are based partially on information gathered during electronic tunnel studies. We need to reconsider these criteria, as the magnitude of fallout remains high at most entrances.

6) Conduct tests to determine the effects of shad and resident fish species on migration success of adult salmonids. Look specifically at impedance of fish passage by concentrations of resident species in the fishway and pre-spawning mortalities associated with transmission of disease.

7) Continue to develop technologies suitable for evaluating passage of adult salmon and steelhead at dams on the Columbia and Snake rivers. Verify results using alternate technologies wherever possible to ensure validity of data collected.

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## APPENDIX A

Minimum, Maximum, Median, and Standard Deviation Values for Total Daily Upstream and Downstream Counts at Fishway Entrances During Study Periods at Lower Granite Dam

Appendix Table A-1. Minimum, maximum, median, and standard deviation values for total daily upstream and downstream electronic tunnel fish counts at fishway entrances during the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

| | | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| Period, entrance | *N* | Min | Max | Median | SD | Min | Max | Median | SD |
| Spring, | | | | | | | | | |
| SSE | 48 | 35 | 1877 | 496.80 | 421.01 | 27 | 2953 | 723.50 | 730.46 |
| FOG-1 | 48 | 2 | 468 | 41.00 | 80.56 | 0 | 100 | 15.00 | 22.64 |
| FOG-4 | 48 | 9 | 249 | 80.50 | 64.65 | 0 | 46 | 11.00 | 10.05 |
| FOG-7 | 48 | 3 | 360 | 83.00 | 82.55 | 0 | 67 | 8.70 | 12.43 |
| FOG-10 | 48 | 0 | 223 | 38.00 | 49.71 | 0 | 75 | 7.00 | 11.75 |
| NPE-1 | 32 | 5 | 204 | 43.50 | 49.81 | 15 | 423 | 75.83 | 95.66 |
| NPE-2 | 32 | 2 | 196 | 50.67 | 57.26 | 19 | 426 | 214.25 | 112.01 |
| NPE-3 | 32 | 0 | 258 | 31.50 | 58.50 | 0 | 234 | 17.40 | 51.74 |
| NSE | 48 | 59 | 2412 | 612.10 | 484.70 | 46 | 938 | 364.00 | 205.68 |
| Summer, | | | | | | | | | |
| SSE | 48 | 21 | 1546 | 398.50 | 445.45 | 41 | 2803 | 850.30 | 780.28 |
| FOG-1 | 47 | 3 | 197 | 28.00 | 33.94 | 0 | 331 | 49.00 | 77.17 |
| FOG-4 | 48 | 0 | 209 | 48.38 | 39.67 | 0 | 67 | 14.50 | 16.25 |
| FOG-7 | 48 | 0 | 176 | 14.00 | 31.52 | 2 | 207 | 14.00 | 30.65 |
| FOG-10 | 48 | 0 | 43 | 11.50 | 10.98 | 0 | 47 | 11.00 | 13.36 |
| NPE-1 | 32 | 0 | 110 | 7.00 | 26.98 | 9 | 240 | 111.00 | 69.19 |
| NPE-2 | 32 | 0 | 221 | 11.50 | 47.06 | 18 | 414 | 161.30 | 112.60 |
| NPE-3 | 32 | 0 | 319 | 29.00 | 72.34 | 0 | 287 | 34.00 | 68.04 |
| NSE | 48 | 122 | 3010 | 940.00 | 674.15 | 52 | 887 | 325.13 | 195.89 |
| Fall, | | | | | | | | | |
| SSE | 63 | 27 | 2352 | 177.30 | 346.39 | 34 | 1538 | 219.80 | 775.14 |
| FOG-1 | 63 | 0 | 1091 | 67.67 | 248.93 | 0 | 494 | 37.80 | 93.08 |
| FOG-4 | 63 | 0 | 263 | 11.20 | 46.97 | 0 | 43 | 8.40 | 10.75 |
| FOG-7 | 63 | 0 | 120 | 8.40 | 25.22 | 0 | 42 | 8.40 | 12.62 |
| FOG-10 | 63 | 0 | 125 | 14.00 | 30.75 | 0 | 50 | 7.00 | 12.52 |
| NPE-1 | 44 | 0 | 288 | 13.30 | 48.95 | 15 | 652 | 100.80 | 127.17 |
| NPE-2 | 35 | 1 | 112 | 18.20 | 23.09 | 29 | 923 | 114.30 | 198.97 |
| NPE-3 | 49 | 0 | 302 | 42.00 | 66.98 | 0 | 353 | 12.60 | 62.87 |
| NSE | 63 | 10 | 609 | 163.80 | 154.56 | 14 | 998 | 137.20 | 221.29 |

Appendix Table A-2. Minimum, maximum, median, and standard deviation values for total daily upstream and downstream underwater video camera fish counts at fishway entrances during the summer (11 June - 22 July) and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

| Period, entrance | *N* | Upstream counts Min | Max | Median | SD | Downstream counts Min | Max | Median | SD |
|---|---|---|---|---|---|---|---|---|---|
| Summer, | | | | | | | | | |
| SSE | 39 | 3 | 398 | 42.96 | 112.35 | 0 | 348 | 28.00 | 92.06 |
| FOG-1 | 13 | 12 | 172 | 32.17 | 43.38 | 5 | 91 | 36.33 | 22.15 |
| FOG-4 | 14 | 0 | 23 | 5.25 | 6.54 | 0 | 42 | 4.50 | 13.36 |
| FOG-7 | 11 | 8 | 51 | 17.50 | 13.41 | 0 | 34 | 9.17 | 12.25 |
| NPE-1 | 25 | 0 | 11 | 2.00 | 2.52 | 0 | 250 | 28.00 | 72.59 |
| NPE-2 | 27 | 0 | 77 | 2.00 | 22.55 | 9 | 1190 | 92.00 | 375.14 |
| NSE | 39 | 3 | 373 | 167.24 | 108.62 | 0 | 243 | 23.50 | 65.03 |
| Fall, | | | | | | | | | |
| SSE | 60 | 35 | 2668 | 447.00 | 519.49 | 26 | 1034 | 220.25 | 229.44 |
| FOG-1 | 9 | 37 | 483 | 266.67 | 166.17 | 14 | 50 | 36.00 | 10.91 |
| FOG-4 | 14 | 7 | 61 | 18.00 | 20.83 | 0 | 45 | 14.00 | 11.67 |
| FOG-7 | 20 | 0 | 34 | 3.17 | 8.18 | 0 | 9 | 1.11 | 2.28 |
| FOG-10 | 18 | 7 | 141 | 37.50 | 37.23 | 5 | 38 | 12.00 | 7.89 |
| NPE-1 | 39 | 0 | 150 | 10.00 | 38.59 | 12 | 2313 | 162.00 | 461.44 |
| NPE-2 | 34 | 0 | 99 | 19.50 | 30.15 | 17 | 1947 | 171.00 | 428.16 |
| NSE | 60 | 8 | 1788 | 185.38 | 408.40 | 3 | 2673 | 155.00 | 601.77 |

## APPENDIX B

Multiple Correlations of Powerhouse, Fishway, and Environmental Variables
for the Spring, Summer, and Fall Study Periods
at Lower Granite Dam

Appendix Table B-1. Correlation analysis between daily passage estimates[a], and operational[b] and environmental[c] variables during the spring (29 April - 10 June) at Lower Granite Dam, Snake River, 1992. Values include Spearman Rank correlation coefficient (r), *P* - values (*P*), and number of days (*N*). Passage estimates are from electronic tunnels.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| SSE, Upstream | | | | | | | | | |
| SSE | 1.0000 | 0.0000 | 38 | 0.8696 | 0.0001 | 38 | -- | -- | -- |
| NSE | 0.7840 | 0.0001 | 38 | 0.6735 | 0.0001 | 38 | -- | -- | -- |
| FOG-1 | 0.4173 | 0.0091 | 38 | 0.6709 | 0.0001 | 38 | -- | -- | -- |
| FOG-4 | 0.5096 | 0.0011 | 38 | 0.5267 | 0.0007 | 38 | -- | -- | -- |
| FOG-7 | 0.3664 | 0.0237 | 38 | 0.6580 | 0.0001 | 38 | -- | -- | -- |
| FOG-10 | 0.0945 | 0.5724 | 38 | 0.6306 | 0.0001 | 38 | -- | -- | -- |
| NPE-1 | 0.6073 | 0.0010 | 26 | 0.6090 | 0.0010 | 26 | -- | -- | -- |
| NPE-2 | 0.4437 | 0.0232 | 26 | 0.4996 | 0.0094 | 26 | -- | -- | -- |
| NPE-3 | 0.1099 | 0.6093 | 24 | 0.4512 | 0.0273 | 24 | -- | -- | -- |
| SUM | 0.9411 | 0.0001 | 38 | 0.9399 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.1110 | 0.5132 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.0797 | 0.6345 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.5335 | 0.0007 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.2183 | 0.1879 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.3299 | 0.0223 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.4952 | 0.0016 | 38 |
| SSE, Downstream | | | | | | | | | |
| NSE | 0.8129 | 0.0001 | 38 | 0.5030 | 0.0013 | 38 | -- | -- | -- |
| FOG-1 | 0.1505 | 0.3671 | 38 | 0.7495 | 0.0001 | 38 | -- | -- | -- |
| FOG-4 | 0.5926 | 0.0001 | 38 | 0.6723 | 0.0001 | 38 | -- | -- | -- |
| FOG-7 | 0.4524 | 0.0043 | 38 | 0.8604 | 0.0001 | 38 | -- | -- | -- |
| FOG-10 | -0.1437 | 0.3893 | 38 | 0.5982 | 0.0001 | 38 | -- | -- | -- |
| NPE-1 | 0.5370 | 0.0047 | 26 | 0.3670 | 0.0652 | 26 | -- | -- | -- |
| NPE-2 | 0.4594 | 0.0182 | 26 | 0.6083 | 0.0010 | 26 | -- | -- | -- |
| NPE-3 | 0.1003 | 0.6410 | 24 | 0.3199 | 0.1275 | 24 | -- | -- | -- |
| SUM | 0.8411 | 0.0001 | 38 | 0.9298 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.2621 | 0.1171 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.3614 | 0.0258 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.7540 | 0.0001 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.5448 | 0.0004 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.4501 | 0.0046 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.5215 | 0.0008 | 38 |
| NSE, Upstream | | | | | | | | | |
| NSE | 1.0000 | 0.0000 | 38 | 0.7289 | 0.0001 | 38 | -- | -- | -- |

Appendix Table B-1. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | P | N | r | P | N | r | P | N |
| FOG-1 | 0.7863 | 0.0001 | 38 | 0.2650 | 0.1079 | 38 | -- | -- | -- |
| FOG-4 | 0.4092 | 0.0107 | 38 | 0.6459 | 0.0001 | 38 | -- | -- | -- |
| FOG-7 | 0.2391 | 0.1482 | 38 | 0.7020 | 0.0001 | 38 | -- | -- | -- |
| FOG-10 | 0.0424 | 0.8006 | 38 | 0.5871 | 0.0001 | 38 | -- | -- | -- |
| NPE-1 | 0.6314 | 0.0005 | 26 | 0.5262 | 0.0058 | 26 | -- | -- | -- |
| NPE-2 | 0.4248 | 0.0305 | 26 | 0.6022 | 0.0011 | 26 | -- | -- | -- |
| NPE-3 | 0.1950 | 0.3614 | 24 | 0.4707 | 0.0203 | 24 | -- | -- | -- |
| SUM | 0.8930 | 0.0001 | 38 | 0.8807 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.1644 | 0.3308 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.0670 | 0.6766 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.7147 | 0.0001 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1934 | 0.2448 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.2901 | 0.0772 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.5469 | 0.0004 | 38 |
| NSE, Downstream | | | | | | | | | |
| FOG-1 | 0.3840 | 0.0173 | 38 | 0.4506 | 0.0045 | 38 | -- | -- | -- |
| FOG-4 | 0.2153 | 0.1943 | 38 | 0.4798 | 0.0023 | 38 | -- | -- | -- |
| FOG-7 | 0.2552 | 0.1220 | 38 | 0.4112 | 0.0103 | 38 | -- | -- | -- |
| FOG-10 | 0.4772 | 0.0025 | 38 | 0.5891 | 0.0001 | 38 | -- | -- | -- |
| NPE-1 | 0.5634 | 0.0027 | 26 | 0.7560 | 0.0001 | 26 | -- | -- | -- |
| NPE-2 | 0.3390 | 0.0903 | 26 | 0.4332 | 0.0270 | 26 | -- | -- | -- |
| NPE-3 | 0.2132 | 0.3172 | 24 | 0.4764 | 0.0186 | 24 | -- | -- | -- |
| SUM | 0.7293 | 0.0001 | 38 | 0.7245 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.2343 | 0.1629 | 37 |
| NET | -- | -- | -- | -- | -- | -- | 0.0378 | 0.8220 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2765 | 0.0976 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.1977 | 0.2341 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.0956 | 0.5681 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2717 | 0.0989 | 38 |
| FOG-1, Upstream | | | | | | | | | |
| FOG-1 | 1.0000 | 0.0000 | 38 | 0.4567 | 0.0039 | 38 | -- | -- | -- |
| FOG-4 | 0.5294 | 0.0006 | 38 | 0.1391 | 0.4049 | 38 | -- | -- | -- |
| FOG-7 | 0.0864 | 0.6059 | 38 | 0.1300 | 0.4365 | 38 | -- | -- | -- |
| FOG-10 | 0.2644 | 0.1086 | 38 | 0.3070 | 0.0608 | 38 | -- | -- | -- |
| NPE-1 | 0.1494 | 0.4665 | 26 | 0.3190 | 0.1122 | 26 | -- | -- | -- |
| NPE-2 | 0.1386 | 0.4997 | 26 | 0.3805 | 0.0552 | 26 | -- | -- | -- |
| NPE-3 | 0.3521 | 0.0915 | 24 | 0.6278 | 0.0010 | 24 | -- | -- | -- |
| SUM | 0.4850 | 0.0020 | 38 | 0.2983 | 0.0689 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.4147 | 0.0107 | 37 |
| NET | -- | -- | -- | -- | -- | -- | 0.3183 | 0.0515 | 38 |

Appendix Table B-1. Continued.

| Variable 1, count direction, variable 2 | Upstream counts r | Upstream counts P | Upstream counts N | Downstream counts r | Downstream counts P | Downstream counts N | Non-directional r | Non-directional P | Non-directional N |
|---|---|---|---|---|---|---|---|---|---|
| TEMP | -- | -- | -- | -- | -- | -- | 0.2000 | 0.2353 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.2687 | 0.1028 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.3142 | 0.0547 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.1958 | 0.2387 | 38 |
| FOG-1, Downstream | | | | | | | | | |
| FOG-4 | 0.5985 | 0.0001 | 38 | 0.6339 | 0.0001 | 38 | -- | -- | -- |
| FOG-7 | 0.2081 | 0.2100 | 38 | 0.7279 | 0.0001 | 38 | -- | -- | -- |
| FOG-10 | -0.1139 | 0.4961 | 38 | 0.5193 | 0.0008 | 38 | -- | -- | -- |
| NPE-1 | 0.4049 | 0.0402 | 26 | 0.2314 | 0.2553 | 26 | -- | -- | -- |
| NPE-2 | 0.2492 | 0.2195 | 26 | 0.6043 | 0.0011 | 26 | -- | -- | -- |
| NPE-3 | 0.3774 | 0.0691 | 24 | 0.5732 | 0.0034 | 24 | -- | -- | -- |
| SUM | 0.7649 | 0.0001 | 38 | 0.7432 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.2099 | 0.2125 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.1222 | 0.4649 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.7906 | 0.0001 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.3282 | 0.0443 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.4436 | 0.0053 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.4619 | 0.0035 | 38 |
| FOG-4, Upstream | | | | | | | | | |
| FOG-4 | 1.0000 | 0.0000 | 38 | 0.5224 | 0.0008 | 38 | -- | -- | -- |
| FOG-7 | 0.2402 | 0.1464 | 38 | 0.6124 | 0.0001 | 38 | -- | -- | -- |
| FOG-10 | -0.0697 | 0.6776 | 38 | 0.4268 | 0.0075 | 38 | -- | -- | -- |
| NPE-1 | 0.2126 | 0.2970 | 26 | -0.0234 | 0.9096 | 26 | -- | -- | -- |
| NPE-2 | 0.2015 | 0.3237 | 26 | 0.0181 | 0.9329 | 24 | -- | -- | -- |
| NPE-3 | -0.0877 | 0.6838 | 24 | 0.0181 | 0.9329 | 24 | -- | -- | -- |
| SUM | 0.5431 | 0.0004 | 38 | 0.5082 | 0.0011 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.0145 | 0.9323 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.2307 | 0.1635 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.4954 | 0.0018 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.3586 | 0.0270 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.6972 | 0.0001 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.4235 | 0.0081 | 38 |
| FOG-4, Downstream | | | | | | | | | |
| FOG-7 | 0.3262 | 0.0457 | 38 | 0.7615 | 0.0001 | 38 | -- | -- | -- |
| FOG-10 | 0.0599 | 0.7211 | 38 | 0.5612 | 0.0002 | 38 | -- | -- | -- |
| NPE-1 | 0.5183 | 0.0067 | 26 | 0.3365 | 0.0928 | 26 | -- | -- | -- |
| NPE-2 | 0.3555 | 0.0747 | 26 | 0.5653 | 0.0026 | 26 | -- | -- | -- |
| NPE-3 | 0.1856 | 0.3852 | 24 | 0.1326 | 0.5368 | 24 | -- | -- | -- |

Appendix Table B-1. Continued.

| Variable 1, count direction, variable 2 | Upstream counts r | P | N | Downstream counts r | P | N | Non-directional r | P | N |
|---|---|---|---|---|---|---|---|---|---|
| SUM | 0.5967 | 0.0001 | 38 | 0.6320 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.3202 | 0.0534 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.2463 | 0.1360 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.6569 | 0.0001 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.4141 | 0.0097 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.2515 | 0.1277 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.4240 | 0.0080 | 38 |
| FOG-7, Upstream | | | | | | | | | |
| FOG-7 | 1.0000 | 0.0000 | 38 | 0.5277 | 0.0007 | 38 | -- | -- | -- |
| FOG-10 | 0.2622 | 0.1118 | 38 | 0.3733 | 0.0210 | 38 | -- | -- | -- |
| NPE-1 | 0.2029 | 0.3202 | 26 | 0.3119 | 0.1209 | 26 | -- | -- | -- |
| NPE-2 | 0.4575 | 0.0188 | 26 | 0.5001 | 0.0093 | 26 | -- | -- | -- |
| NPE-3 | -0.0968 | 0.6526 | 24 | -0.0527 | 0.8068 | 24 | -- | -- | -- |
| SUM | 0.3697 | 0.0224 | 38 | 0.3797 | 0.0187 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.0647 | 0.7034 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.0175 | 0.9169 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2821 | 0.0907 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1602 | 0.3366 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1657 | 0.3200 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.3169 | 0.0526 | 38 |
| FOG-7, Downstream | | | | | | | | | |
| FOG-10 | -0.1098 | 0.5116 | 38 | 0.5362 | 0.0005 | 38 | -- | -- | -- |
| NPE-1 | 0.4676 | 0.0160 | 26 | 0.2516 | 0.2150 | 26 | -- | -- | -- |
| NPE-2 | 0.4826 | 0.0125 | 26 | 0.6934 | 0.0001 | 26 | -- | -- | -- |
| NPE-3 | 0.1600 | 0.4551 | 24 | 0.1256 | 0.5587 | 24 | -- | -- | -- |
| SUM | 0.7074 | 0.0001 | 38 | 0.7547 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.3045 | 0.0669 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.2686 | 0.1030 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.7242 | 0.0001 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.4994 | 0.0014 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.4193 | 0.0088 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.4115 | 0.0103 | 38 |
| FOG-10, Upstream | | | | | | | | | |
| FOG-10 | 1.0000 | 0.0000 | 38 | 0.4052 | 0.0116 | 38 | -- | -- | -- |
| NPE-1 | 0.3350 | 0.0943 | 26 | 0.5310 | 0.0053 | 26 | -- | -- | -- |
| NPE-2 | 0.2716 | 0.1795 | 26 | 0.0255 | 0.9016 | 26 | -- | -- | -- |
| NPE-3 | -0.1359 | 0.5267 | 24 | -0.0824 | 0.7018 | 24 | -- | -- | -- |
| SUM | 0.1593 | 0.3395 | 38 | 0.0335 | 0.8418 | 38 | -- | -- | -- |

Appendix Table B-1. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| COUNT | -- | -- | -- | -- | -- | -- | 0.5826 | 0.0002 | 37 |
| NET | -- | -- | -- | -- | -- | -- | 0.5475 | 0.0004 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.2614 | 0.1182 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.5933 | 0.0001 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.2344 | 0.1566 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.1319 | 0.4298 | 38 |
| FOG-10, Downstream | | | | | | | | | |
| NPE-1 | 0.5393 | 0.0045 | 26 | 0.5321 | 0.0051 | 26 | -- | -- | -- |
| NPE-2 | 0.4216 | 0.0320 | 26 | 0.3804 | 0.0552 | 26 | -- | -- | -- |
| NPE-3 | 0.1710 | 0.4243 | 24 | 0.4014 | 0.0519 | 24 | -- | -- | -- |
| SUM | 0.6663 | 0.0001 | 38 | 0.6540 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.0110 | 0.9485 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.0088 | 0.9583 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.3944 | 0.0157 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1001 | 0.5498 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1801 | 0.2792 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.3516 | 0.0304 | 38 |
| NPE-1, Upstream | | | | | | | | | |
| NPE-1 | 1.0000 | 0.0000 | 26 | 0.7097 | 0.0001 | 26 | -- | -- | -- |
| NPE-2 | 0.6469 | 0.0124 | 14 | 0.6264 | 0.0165 | 14 | -- | -- | -- |
| NPE-3 | 0.0053 | 0.9870 | 12 | 0.0780 | 0.8097 | 12 | -- | -- | -- |
| SUM | 0.6848 | 0.0001 | 26 | 0.6745 | 0.0002 | 26 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.0012 | 0.9956 | 25 |
| NET | -- | -- | -- | -- | -- | -- | 0.1320 | 0.5203 | 26 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.3650 | 0.0728 | 25 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.2032 | 0.3195 | 26 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.0058 | 0.9775 | 26 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.3838 | 0.0529 | 26 |
| NPE-1, Downstream | | | | | | | | | |
| NPE-2 | 0.6733 | 0.0083 | 14 | 0.6659 | 0.0093 | 14 | -- | -- | -- |
| NPE-3 | 0.3627 | 0.2466 | 12 | 0.3551 | 0.2573 | 12 | -- | -- | -- |
| SUM | 0.6747 | 0.0002 | 26 | 0.6487 | 0.0003 | 26 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.2000 | 0.3377 | 25 |
| NET | -- | -- | -- | -- | -- | -- | 0.2161 | 0.2890 | 26 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2780 | 0.1784 | 25 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.3522 | 0.0776 | 26 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.1887 | 0.3560 | 26 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2787 | 0.1681 | 26 |

Appendix Table B-1. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| NPE-2, Upstream | | | | | | | | | |
| NPE-2 | 1.0000 | 0.0000 | 26 | 0.7321 | 0.0001 | 26 | -- | -- | -- |
| NPE-3 | 0.1168 | 0.7177 | 12 | -0.0071 | 0.9826 | 12 | -- | -- | -- |
| SUM | 0.5124 | 0.0074 | 26 | 0.4779 | 0.0136 | 26 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.0785 | 0.7091 | 25 |
| NET | -- | -- | -- | -- | -- | -- | -0.0161 | 0.9379 | 26 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.4840 | 0.0142 | 25 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.0210 | 0.9194 | 26 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1616 | 0.4304 | 26 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.3938 | 0.0465 | 26 |
| NPE-2, Downstream | | | | | | | | | |
| NPE-3 | 0.4347 | 0.1579 | 12 | 0.5282 | 0.0775 | 12 | -- | -- | -- |
| SUM | 0.5929 | 0.0014 | 26 | 0.6237 | 0.0007 | 26 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.2151 | 0.3018 | 25 |
| NET | -- | -- | -- | -- | -- | -- | -0.3170 | 0.1146 | 26 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.7166 | 0.0001 | 25 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1576 | 0.4418 | 26 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.2604 | 0.1989 | 26 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2750 | 0.1739 | 26 |
| NPE-3, Upstream | | | | | | | | | |
| NPE-3 | 1.0000 | 0.0000 | 24 | 0.7171 | 0.0001 | 24 | -- | -- | -- |
| SUM | 0.1945 | 0.3625 | 24 | 0.1766 | 0.4091 | 24 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.1374 | 0.5221 | 24 |
| NET | -- | -- | -- | -- | -- | -- | 0.0772 | 0.7200 | 24 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.4312 | 0.0354 | 24 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.1953 | 0.3603 | 24 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.2178 | 0.3066 | 24 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.1597 | 0.4560 | 24 |
| NPE-3, Downstream | | | | | | | | | |
| SUM | 0.4913 | 0.0148 | 24 | 0.4445 | 0.0295 | 24 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.0297 | 0.8903 | 24 |
| NET | -- | -- | -- | -- | -- | -- | 0.0695 | 0.7469 | 24 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.4289 | 0.0365 | 24 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.2002 | 0.3483 | 24 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.0641 | 0.7660 | 24 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2012 | 0.3457 | 24 |

Appendix Table B-1. Continued.

| Variable 1, count direction, variable 2 | Upstream counts r | Upstream counts P | Upstream counts N | Downstream counts r | Downstream counts P | Downstream counts N | Non-directional r | Non-directional P | Non-directional N |
|---|---|---|---|---|---|---|---|---|---|
| SUM, Upstream | | | | | | | | | |
| SUM | 1.0000 | 0.0000 | 38 | 0.9400 | 0.0001 | 38 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.0934 | 0.5824 | 37 |
| NET | -- | -- | -- | -- | -- | -- | 0.0375 | 0.8230 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.6349 | 0.0001 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1073 | 0.5212 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.3469 | 0.0329 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.5849 | 0.0001 | 38 |
| SUM, Downstream | | | | | | | | | |
| COUNT | -- | -- | -- | -- | -- | -- | -0.0780 | 0.6463 | 37 |
| NET | -- | -- | -- | -- | -- | -- | -0.2518 | 0.1273 | 38 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.6805 | 0.0001 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.2975 | 0.0697 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.3155 | 0.0536 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.5120 | 0.0010 | 38 |
| COUNT, | | | | | | | | | |
| NET | -- | -- | -- | -- | -- | -- | 0.5630 | 0.0003 | 37 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.4902 | 0.0013 | 40 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.6024 | 0.0001 | 40 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.0330 | 0.8401 | 40 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.0083 | 0.9594 | 40 |
| NET, | | | | | | | | | |
| TEMP | -- | -- | -- | -- | -- | -- | -0.2746 | 0.1000 | 37 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.6100 | 0.0001 | 38 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.1311 | 0.4329 | 38 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.0679 | 0.6856 | 38 |

[a] *SUM: Total of daily upstream or downstream counts of adult salmonids from all entrances.*
*NET: (SUM of upstream counts - SUM of downstream counts).*
*COUNT: Total daily counts of adult salmonids passing the fish ladder viewing window.*

[b] *KCFS: Mean hourly turbine discharge per day.*
*SOUTH: Mean daily surface water velocity in the south shore collection channel.*
*NORTH: Mean daily surface water velocity in the north powerhouse collection channel.*

[c] *TEMP: Daily forebay water temperature.*

Appendix Table B-2. Correlation analysis between daily passage estimates[a], and operational[b] and environmental[c] variables during the summer (11 June - 22 July) at Lower Granite Dam, Snake River, 1992. Values include Spearman Rank correlation coefficient (r), *P* - values (*P*), and number of days (*N*). Passage estimates are from video data.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| SSE, Upstream | | | | | | | | | |
| SSE | 1.0000 | 0.0000 | 42 | 0.8126 | 0.0001 | 42 | -- | -- | -- |
| NSE | 0.6513 | 0.0001 | 42 | 0.2348 | 0.1345 | 42 | -- | -- | -- |
| FOG-1 | -0.2712 | 0.3483 | 14 | 0.5022 | 0.0673 | 14 | -- | -- | -- |
| FOG-4 | -0.0471 | 0.8677 | 15 | 0.4626 | 0.0825 | 15 | -- | -- | -- |
| FOG-7 | 0.1018 | 0.7530 | 12 | 0.0914 | 0.7776 | 12 | -- | -- | -- |
| NPE-1 | 0.3778 | 0.0520 | 27 | 0.3402 | 0.0825 | 27 | -- | -- | -- |
| NPE-2 | 0.6641 | 0.0001 | 30 | 0.6702 | 0.0001 | 30 | -- | -- | -- |
| SUM | 0.8009 | 0.0001 | 42 | 0.7098 | 0.0001 | 42 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.2815 | 0.0826 | 39 |
| NET | -- | -- | -- | -- | -- | -- | -0.0114 | 0.9431 | 42 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.4870 | 0.0017 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.0901 | 0.5703 | 42 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.0423 | 0.7902 | 42 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0386 | 0.8085 | 42 |
| SSE, Downstream | | | | | | | | | |
| NSE | 0.5071 | 0.0006 | 42 | 0.2145 | 0.1725 | 42 | -- | -- | -- |
| FOG-1 | -0.2712 | 0.3483 | 14 | -0.2819 | 0.3288 | 14 | -- | -- | -- |
| FOG-4 | 0.0208 | 0.9413 | 15 | 0.4896 | 0.0640 | 15 | -- | -- | -- |
| FOG-7 | 0.4316 | 0.1612 | 12 | 0.2847 | 0.3698 | 12 | -- | -- | -- |
| NPE-1 | 0.3387 | 0.0839 | 27 | 0.4216 | 0.0285 | 27 | -- | -- | -- |
| NPE-2 | 0.6693 | 0.0001 | 30 | 0.7012 | 0.0001 | 30 | -- | -- | -- |
| SUM | 0.6028 | 0.0001 | 42 | 0.7305 | 0.0001 | 42 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.0610 | 0.7124 | 39 |
| NET | -- | -- | -- | -- | -- | -- | -0.3471 | 0.0243 | 42 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.4624 | 0.0030 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1629 | 0.3026 | 42 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.0272 | 0.8641 | 42 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.1605 | 0.3099 | 42 |
| NSE, Upstream | | | | | | | | | |
| NSE | 1.0000 | 0.0000 | 42 | 0.5749 | 0.0001 | 42 | -- | -- | -- |
| FOG-1 | 0.3109 | 0.2793 | 14 | -0.1366 | 0.6416 | 14 | -- | -- | -- |
| FOG-4 | -0.0535 | 0.8500 | 15 | 0.1418 | 0.6141 | 15 | -- | -- | -- |
| FOG-7 | 0.2421 | 0.4484 | 12 | 0.0668 | 0.8366 | 12 | -- | -- | -- |
| NPE-1 | -0.0896 | 0.6569 | 27 | 0.0174 | 0.9313 | 27 | -- | -- | -- |

Appendix Table B-2. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| NPE-2 | 0.7027 | 0.0001 | 30 | 0.5687 | 0.0010 | 30 | -- | -- | -- |
| SUM | 0.9497 | 0.0001 | 42 | 0.6743 | 0.0001 | 42 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.3879 | 0.0147 | 39 |
| NET | -- | -- | -- | -- | -- | -- | 0.1556 | 0.3251 | 42 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.1488 | 0.3661 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1654 | 0.2953 | 42 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.1170 | 0.4606 | 42 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.0189 | 0.9053 | 42 |
| NSE, Downstream | | | | | | | | | |
| FOG-1 | -0.0441 | 0.8810 | 14 | -0.5903 | 0.0263 | 14 | -- | -- | -- |
| FOG-4 | -0.0567 | 0.8410 | 15 | -0.0536 | 0.8496 | 15 | -- | -- | -- |
| FOG-7 | -0.2842 | 0.3706 | 12 | -0.6151 | 0.0333 | 12 | -- | -- | -- |
| NPE-1 | 0.0249 | 0.9019 | 27 | -0.0329 | 0.8707 | 27 | -- | -- | -- |
| NPE-2 | 0.5990 | 0.0005 | 30 | 0.6860 | 0.0001 | 30 | -- | -- | -- |
| SUM | 0.5359 | 0.0003 | 42 | 0.5305 | 0.0003 | 42 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.1849 | 0.2597 | 39 |
| NET | -- | -- | -- | -- | -- | -- | -0.1680 | 0.2875 | 42 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.0578 | 0.7269 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1459 | 0.3565 | 42 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.0375 | 0.8138 | 42 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2409 | 0.1243 | 42 |
| FOG-1, Upstream | | | | | | | | | |
| FOG-1 | 1.0000 | 0.0000 | 14 | 0.1147 | 0.6963 | 14 | -- | -- | -- |
| NPE-1 | -0.2070 | 0.6939 | 06 | 0.4857 | 0.3287 | 06 | -- | -- | -- |
| NPE-2 | -0.0121 | 0.9774 | 08 | 0.0602 | 0.8873 | 08 | -- | -- | -- |
| SUM | 0.0353 | 0.9047 | 14 | -0.0728 | 0.8047 | 14 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.2256 | 0.4587 | 13 |
| NET | -- | -- | -- | -- | -- | -- | 0.1588 | 0.5877 | 14 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.0255 | 0.9340 | 13 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.0573 | 0.8458 | 14 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.3348 | 0.2420 | 14 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.1114 | 0.7047 | 14 |
| FOG-1, Downstream | | | | | | | | | |
| NPE-1 | 0.0000 | 1.0000 | 06 | 0.6000 | 0.2080 | 06 | -- | -- | -- |
| NPE-2 | -0.1325 | 0.7544 | 08 | -0.5904 | 0.1234 | 08 | -- | -- | -- |
| SUM | 0.3216 | 0.2622 | 14 | -0.4537 | 0.1032 | 14 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.5604 | 0.0463 | 13 |
| NET | -- | -- | -- | -- | -- | -- | 0.5419 | 0.0453 | 14 |

Appendix Table B-2. Continued.

| Varialbe 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| TEMP | -- | -- | -- | -- | -- | -- | 0.7482 | 0.0033 | 13 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.3190 | 0.2662 | 14 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.2706 | 0.3494 | 14 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.2566 | 0.3758 | 14 |
| FOG-4, Upstream | | | | | | | | | |
| FOG-4 | 1.0000 | 0.0000 | 15 | 0.2405 | 0.3878 | 15 | -- | -- | -- |
| NPE-1 | 0.3603 | 0.3806 | 08 | -0.4121 | 0.3103 | 08 | -- | -- | -- |
| NPE-2 | 0.0523 | 0.8531 | 15 | -0.0815 | 0.7727 | 15 | -- | -- | -- |
| SUM | 0.3312 | 0.2278 | 15 | -0.0760 | 0.7877 | 15 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.0825 | 0.7792 | 14 |
| NET | -- | -- | -- | -- | -- | -- | 0.1050 | 0.7096 | 15 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.1062 | 0.7178 | 14 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.0289 | 0.9185 | 15 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.3942 | 0.1459 | 15 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.1989 | 0.4772 | 15 |
| FOG-4, Downstream | | | | | | | | | |
| NPE-1 | 0.5733 | 0.1374 | 08 | -0.5966 | 0.1185 | 08 | -- | -- | -- |
| NPE-2 | 0.2254 | 0.4192 | 15 | -0.0549 | 0.8459 | 15 | -- | -- | -- |
| SUM | 0.5376 | 0.0387 | 15 | 0.1042 | 0.7116 | 15 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.1510 | 0.6065 | 14 |
| NET | -- | -- | -- | -- | -- | -- | 0.1426 | 0.6121 | 15 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.0799 | 0.7860 | 14 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.3270 | 0.2341 | 15 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.1242 | 0.6591 | 15 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.4220 | 0.1171 | 15 |
| FOG-7, Upstream | | | | | | | | | |
| FOG-7 | 1.0000 | 0.0000 | 12 | 0.7100 | 0.0097 | 12 | -- | -- | -- |
| NPE-1 | -0.4435 | 0.1487 | 12 | -0.1620 | 0.6150 | 12 | -- | -- | -- |
| NPE-2 | 0.5075 | 0.3041 | 06 | 0.0588 | 0.9119 | 06 | -- | -- | -- |
| SUM | 0.1368 | 0.6715 | 12 | -0.0175 | 0.9568 | 12 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.4091 | 0.2115 | 11 |
| NET | -- | -- | -- | -- | -- | -- | 0.3544 | 0.2584 | 12 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2407 | 0.4758 | 11 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.0245 | 0.9397 | 12 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.2732 | 0.3902 | 12 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.4737 | 0.1198 | 12 |

Appendix Table B-2. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| FOG-7, Downstream | | | | | | | | | |
| NPE-1 | -0.1456 | 0.6517 | 12 | -0.3721 | 0.2336 | 12 | -- | -- | -- |
| NPE-2 | -0.0896 | 0.8660 | 06 | -0.5882 | 0.2194 | 06 | -- | -- | -- |
| SUM | -0.0527 | 0.8707 | 12 | -0.4956 | 0.1013 | 12 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.4100 | 0.2104 | 11 |
| NET | -- | -- | -- | -- | -- | -- | 0.5589 | 0.0589 | 12 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.0615 | 0.8574 | 11 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.0491 | 0.8795 | 12 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.1825 | 0.5703 | 12 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.4007 | 0.1968 | 12 |
| NPE-1, Upstream | | | | | | | | | |
| NPE-1 | 1.0000 | 0.0000 | 27 | 0.4080 | 0.0346 | 27 | -- | -- | -- |
| NPE-2 | 0.0746 | 0.7916 | 15 | 0.1537 | 0.5846 | 15 | -- | -- | -- |
| SUM | 0.0530 | 0.7930 | 27 | 0.3037 | 0.1236 | 27 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.2101 | 0.3134 | 25 |
| NET | -- | -- | -- | -- | -- | -- | -0.0648 | 0.7480 | 27 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2052 | 0.3252 | 25 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.3344 | 0.0882 | 27 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1136 | 0.5726 | 27 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2743 | 0.1662 | 27 |
| NPE-1, Downstream | | | | | | | | | |
| NPE-2 | -0.0493 | 0.8615 | 15 | 0.0540 | 0.8485 | 15 | -- | -- | -- |
| SUM | 0.1094 | 0.5869 | 27 | 0.4854 | 0.0103 | 27 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.3091 | 0.1327 | 25 |
| NET | -- | -- | -- | -- | -- | -- | -0.0373 | 0.8535 | 27 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.7874 | 0.0001 | 25 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.3239 | 0.0993 | 27 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1412 | 0.4824 | 27 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2427 | 0.2225 | 27 |
| NPE-2, Upstream | | | | | | | | | |
| NPE-2 | 1.0000 | 0.0000 | 30 | 0.7005 | 0.0001 | 30 | -- | -- | -- |
| SUM | 0.7344 | 0.0001 | 30 | 0.6810 | 0.0001 | 30 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.0258 | 0.8985 | 27 |
| NET | -- | -- | -- | -- | -- | -- | -0.4900 | 0.0060 | 30 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.0721 | 0.7207 | 27 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.3455 | 0.0615 | 30 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.0563 | 0.7677 | 30 |

Appendix Table B-2. Continued.

| Variable 1, count direction, variable 2 | Upstream counts r | P | N | Downstream counts r | P | N | Non-directional r | P | N |
|---|---|---|---|---|---|---|---|---|---|
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0091 | 0.9621 | 30 |
| NPE-2, Downstream | | | | | | | | | |
| SUM | 0.6702 | 0.0001 | 30 | 0.9745 | 0.0001 | 30 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.2392 | 0.2296 | 27 |
| NET | -- | -- | -- | -- | -- | -- | -0.7683 | 0.0001 | 30 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.0044 | 0.9827 | 27 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.2756 | 0.1405 | 30 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.2319 | 0.2175 | 30 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.1292 | 0.4963 | 30 |
| SUM, Upstream | | | | | | | | | |
| SUM | 1.0000 | 0.0000 | 42 | 0.7512 | 0.0001 | 42 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.4350 | 0.0056 | 39 |
| NET | -- | -- | -- | -- | -- | -- | 0.1286 | 0.4172 | 42 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.3079 | 0.0566 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.0346 | 0.8278 | 42 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.0836 | 0.5985 | 42 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.0519 | 0.7440 | 42 |
| SUM, Downstream | | | | | | | | | |
| COUNT | -- | -- | -- | -- | -- | -- | 0.2392 | 0.1424 | 39 |
| NET | -- | -- | -- | -- | -- | -- | -0.4028 | 0.0082 | 42 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2381 | 0.1443 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.2137 | 0.1742 | 42 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1651 | 0.2961 | 42 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.1477 | 0.3507 | 42 |
| COUNT, | | | | | | | | | |
| NET | -- | -- | -- | -- | -- | -- | 0.4335 | 0.0058 | 39 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.0335 | 0.8396 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.3293 | 0.0407 | 39 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.1499 | 0.3622 | 39 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.0550 | 0.7395 | 39 |
| NET, | | | | | | | | | |
| TEMP | | | | | | | 0.0118 | 0.9433 | 39 |
| KCFS | | | | | | | 0.4456 | 0.0031 | 42 |
| NORTH | | | | | | | -0.3266 | 0.0348 | 42 |
| SOUTH | | | | | | | -0.0970 | 0.5408 | 42 |

[a] *SUM: Total of daily upstream or downstream counts of adult salmonids from all entrances.*
*NET: (SUM of upstream counts - SUM of downstream counts).*
*COUNT: Total daily counts of adult salmonids passing the fish ladder viewing window.*
[b] *KCFS: Mean hourly turbine discharge per day.*
*SOUTH: Mean daily surface water velocity in the south shore collection channel.*
*NORTH: Mean daily surface water velocity in the north powerhouse collection channel.*

[c] *TEMP: Daily forebay water temperature.*

Appendix Table B-3. Correlation analysis between daily passage estimates[a], and operational[b] and environmental[c] variables during the fall (9 September - 10 November) at Lower Granite Dam, Snake River, 1992. Values include Spearman Rank correlation coefficient (r), *P* - values (*P*), and number of days (*N*). Passage estimates are from video data.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| SSE, Upstream | | | | | | | | | |
| SSE | 1.0000 | 0.0000 | 63 | 0.7559 | 0.0001 | 63 | -- | -- | -- |
| NSE | 0.5540 | 0.0001 | 63 | 0.4086 | 0.0009 | 63 | -- | -- | -- |
| FOG-1 | 0.1342 | 0.7118 | 10 | 0.5854 | 0.0754 | 10 | -- | -- | -- |
| FOG-4 | -0.1325 | 0.6378 | 15 | 0.5252 | 0.0444 | 15 | -- | -- | -- |
| FOG-7 | 0.4737 | 0.0301 | 21 | 0.1557 | 0.5005 | 21 | -- | -- | -- |
| FOG-10 | 0.4039 | 0.0964 | 18 | 0.5982 | 0.0087 | 18 | -- | -- | -- |
| NPE-1 | 0.1541 | 0.3300 | 42 | 0.8036 | 0.0001 | 42 | -- | -- | -- |
| NPE-2 | 0.2404 | 0.1518 | 37 | 0.5666 | 0.0003 | 37 | -- | -- | -- |
| SUM | 0.8856 | 0.0001 | 63 | 0.8177 | 0.0001 | 63 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.6896 | 0.0001 | 59 |
| NET | -- | -- | -- | -- | -- | -- | 0.1886 | 0.1388 | 63 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.0352 | 0.7912 | 59 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.3705 | 0.0028 | 63 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1485 | 0.2453 | 63 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0032 | 0.9800 | 63 |
| SSE, Downstream | | | | | | | | | |
| NSE | 0.4128 | 0.0008 | 63 | 0.1878 | 0.1406 | 63 | -- | -- | -- |
| FOG-1 | 0.3659 | 0.2985 | 10 | 0.8171 | 0.0039 | 10 | -- | -- | -- |
| FOG-4 | -0.2022 | 0.4700 | 15 | 0.3935 | 0.1467 | 15 | -- | -- | -- |
| FOG-7 | 0.3688 | 0.0999 | 21 | -0.1934 | 0.4009 | 21 | -- | -- | -- |
| FOG-10 | 0.5847 | 0.0108 | 18 | 0.6921 | 0.0015 | 18 | -- | -- | -- |
| NPE-1 | -0.1393 | 0.3788 | 42 | 0.6974 | 0.0001 | 42 | -- | -- | -- |

Appendix Table B-3 Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| NPE-2 | 0.0815 | 0.6314 | 37 | 0.4390 | 0.0066 | 37 | -- | -- | -- |
| SUM | 0.7074 | 0.0001 | 63 | 0.7268 | 0.0001 | 63 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.6236 | 0.0001 | 59 |
| NET | -- | -- | -- | -- | -- | -- | 0.0347 | 0.7873 | 63 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.0332 | 0.5819 | 59 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.5398 | 0.0001 | 63 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1243 | 0.3318 | 63 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0892 | 0.4871 | 63 |
| NSE, Upstream | | | | | | | | | |
| NSE | 1.0000 | 0.0000 | 63 | 0.8078 | 0.0001 | 63 | -- | -- | -- |
| FOG-1 | 0.4878 | 0.1526 | 10 | 0.6342 | 0.0489 | 10 | -- | -- | -- |
| FOG-4 | -0.2272 | 0.4155 | 15 | 0.2695 | 0.3313 | 15 | -- | -- | -- |
| FOG-7 | 0.3603 | 0.1086 | 21 | 0.0074 | 0.9746 | 21 | -- | -- | -- |
| FOG-10 | 0.3957 | 0.1041 | 18 | 0.5167 | 0.0281 | 18 | -- | -- | -- |
| NPE-1 | -0.0685 | 0.6663 | 42 | 0.6778 | 0.0001 | 42 | -- | -- | -- |
| NPE-2 | 0.5184 | 0.0010 | 37 | 0.8092 | 0.0001 | 37 | -- | -- | -- |
| SUM | 0.8010 | 0.0001 | 63 | 0.7924 | 0.0001 | 63 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.8392 | 0.0001 | 59 |
| NET | -- | -- | -- | -- | -- | -- | 0.0349 | 0.7861 | 63 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.5986 | 0.0001 | 59 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1146 | 0.3713 | 63 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.5515 | 0.0001 | 63 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0125 | 0.9226 | 63 |
| NSE, Downstream | | | | | | | | | |
| FOG-1 | 0.5122 | 0.1301 | 10 | 0.8171 | 0.0039 | 10 | -- | -- | -- |
| FOG-4 | 0.7066 | 0.0032 | 15 | 0.3576 | 0.1907 | 15 | -- | -- | -- |
| FOG-7 | 0.6499 | 0.0014 | 21 | 0.3885 | 0.0818 | 21 | -- | -- | -- |
| FOG-10 | 0.6550 | 0.0032 | 18 | 0.6274 | 0.0053 | 18 | -- | -- | -- |
| NPE-1 | -0.0284 | 0.8586 | 42 | 0.6180 | 0.0001 | 42 | -- | -- | -- |
| NPE-2 | 0.5246 | 0.0009 | 37 | 0.5921 | 0.0001 | 37 | -- | -- | -- |
| SUM | 0.6829 | 0.0001 | 63 | 0.7290 | 0.0001 | 63 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.7330 | 0.0001 | 59 |
| NET | -- | -- | -- | -- | -- | -- | -0.1818 | 0.1540 | 63 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.5739 | 0.0001 | 59 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.0584 | 0.6494 | 63 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.5489 | 0.0001 | 63 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0761 | 0.5531 | 63 |

Appendix Table B-3. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| FOG-1, Upstream | | | | | | | | | |
| FOG-1 | 1.0000 | 0.0000 | 10 | 0.6463 | 0.0435 | 10 | -- | -- | -- |
| NPE-1 | 0.6761 | 0.1404 | 06 | 0.7714 | 0.0724 | 06 | -- | -- | -- |
| NPE-2 | -0.3333 | 0.6667 | 04 | 0.7778 | 0.2222 | 04 | -- | -- | -- |
| SUM | 0.6585 | 0.0384 | 10 | 0.6098 | 0.0612 | 10 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.5667 | 0.1116 | 09 |
| NET | -- | -- | -- | -- | -- | -- | 0.4268 | 0.2186 | 10 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.7942 | 0.0106 | 09 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.4863 | 0.1541 | 10 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.0365 | 0.9203 | 10 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.1216 | 0.7379 | 10 |
| FOG-1, Downstream | | | | | | | | | |
| NPE-1 | 0.8452 | 0.0341 | 06 | 0.9429 | 0.0048 | 06 | -- | -- | -- |
| NPE-2 | 0.3333 | 0.6667 | 04 | 1.0000 | 0.0000 | 04 | -- | -- | -- |
| SUM | 0.8415 | 0.0023 | 10 | 0.9390 | 0.0001 | 10 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.8000 | 0.0096 | 09 |
| NET | -- | -- | -- | -- | -- | -- | 0.2073 | 0.5655 | 10 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.1004 | 0.7971 | 09 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.0365 | 0.9203 | 10 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.2067 | 0.5667 | 10 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2189 | 0.5436 | 10 |
| FOG-4, Upstream | | | | | | | | | |
| FOG-4 | 1.0000 | 0.0000 | 15 | 0.6505 | 0.0086 | 15 | -- | -- | -- |
| NPE-1 | -0.0400 | 0.9186 | 09 | -0.3376 | 0.3743 | 09 | -- | -- | -- |
| NPE-2 | -0.0184 | 0.9599 | 10 | -0.5321 | 0.1134 | 10 | -- | -- | -- |
| SUM | 0.2220 | 0.4264 | 15 | 0.2650 | 0.3398 | 15 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.2747 | 0.3637 | 13 |
| NET | -- | -- | -- | -- | -- | -- | -0.1862 | 0.5064 | 15 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.2185 | 0.4732 | 13 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.2699 | 0.3307 | 15 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.0054 | 0.9848 | 15 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.5722 | 0.0258 | 15 |
| FOG-4, Downstream | | | | | | | | | |
| NPE-1 | 0.5374 | 0.1357 | 09 | -0.2924 | 0.4452 | 09 | -- | -- | -- |
| NPE-2 | -0.6923 | 0.0265 | 10 | -0.3539 | 0.3158 | 10 | -- | -- | -- |
| SUM | 0.6403 | 0.0101 | 15 | 0.4694 | 0.0775 | 15 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.6390 | 0.0187 | 13 |

Appendix Table B-3. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| NET | -- | -- | -- | -- | -- | -- | 0.4622 | 0.0828 | 15 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.1814 | 0.5531 | 13 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.4650 | 0.0807 | 15 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.0486 | 0.8635 | 15 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.2883 | 0.2974 | 15 |
| FOG-7, Upstream | | | | | | | | | |
| FOG-7 | 1.0000 | 0.0000 | 21 | 0.5622 | 0.0080 | 21 | -- | -- | -- |
| NPE-1 | 0.4179 | 0.1211 | 15 | 0.6000 | 0.0181 | 15 | -- | -- | -- |
| NPE-2 | 0.5696 | 0.0421 | 13 | 0.7330 | 0.0044 | 13 | -- | -- | -- |
| SUM | 0.4186 | 0.0589 | 21 | 0.4022 | 0.0707 | 21 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.5444 | 0.0131 | 20 |
| NET | -- | -- | -- | -- | -- | -- | -0.0328 | 0.8879 | 21 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.3849 | 0.0938 | 20 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.4237 | 0.0556 | 21 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1624 | 0.4820 | 21 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.3477 | 0.1225 | 21 |
| FOG-7, Downstream | | | | | | | | | |
| NPE-1 | 0.3939 | 0.1463 | 15 | 0.4479 | 0.0941 | 15 | -- | -- | -- |
| NPE-2 | 0.0360 | 0.9072 | 13 | 0.2413 | 0.4271 | 13 | -- | -- | -- |
| SUM | 0.0937 | 0.6863 | 21 | 0.0263 | 0.9100 | 21 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.4222 | 0.0637 | 20 |
| NET | -- | -- | -- | -- | -- | -- | 0.0815 | 0.7253 | 21 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2404 | 0.3072 | 20 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.1960 | 0.3944 | 21 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1123 | 0.6278 | 21 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2490 | 0.2765 | 21 |
| FOG-10, Upstream | | | | | | | | | |
| FOG-10 | 1.0000 | 0.0000 | 18 | 0.7148 | 0.0009 | 18 | -- | -- | -- |
| NPE-1 | 0.7349 | 0.0065 | 12 | 0.6655 | 0.0182 | 12 | -- | -- | -- |
| NPE-2 | 0.2719 | 0.4186 | 11 | 0.5754 | 0.0640 | 11 | -- | -- | -- |
| SUM | 0.4070 | 0.0937 | 18 | 0.6219 | 0.0059 | 18 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.5434 | 0.0198 | 18 |
| NET | -- | -- | -- | -- | -- | -- | -0.6426 | 0.0040 | 18 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.3063 | 0.2164 | 18 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.3357 | 0.1732 | 18 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1953 | 0.4375 | 18 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.3121 | 0.2073 | 18 |

Appendix Table B-3. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| FOG-10, Downstream | | | | | | | | | |
| NPE-1 | 0.7221 | 0.0080 | 12 | 0.6046 | 0.0373 | 12 | -- | -- | -- |
| NPE-2 | 0.5024 | 0.1153 | 11 | 0.7025 | 0.0159 | 11 | -- | -- | -- |
| SUM | 0.5439 | 0.0196 | 18 | 0.6848 | 0.0017 | 18 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.6629 | 0.0027 | 18 |
| NET | -- | -- | -- | -- | -- | -- | -0.5251 | 0.0252 | 18 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.4217 | 0.0813 | 18 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.0929 | 0.7139 | 18 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.0218 | 0.9116 | 18 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.3436 | 0.1627 | 18 |
| NPE-1, Upstream | | | | | | | | | |
| NPE-1 | 1.0000 | 0.0000 | 42 | -0.0251 | 0.8745 | 42 | -- | -- | -- |
| NPE-2 | 0.5094 | 0.0308 | 18 | 0.6424 | 0.0040 | 18 | -- | -- | -- |
| SUM | 0.0727 | 0.6473 | 42 | -0.0793 | 0.6176 | 42 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | -0.0665 | 0.6876 | 39 |
| NET | -- | -- | -- | -- | -- | -- | 0.1482 | 0.3490 | 42 |
| TEMP | -- | -- | -- | -- | -- | -- | -0.5227 | 0.0006 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.3593 | 0.0195 | 42 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.3510 | 0.0227 | 42 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.0770 | 0.6279 | 42 |
| NPE-1, Downstream | | | | | | | | | |
| NPE-2 | -0.1919 | 0.4455 | 18 | 0.4793 | 0.0442 | 18 | -- | -- | -- |
| SUM | 0.8615 | 0.0001 | 42 | 0.8479 | 0.0001 | 42 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.7746 | 0.0001 | 39 |
| NET | -- | -- | -- | -- | -- | -- | 0.0711 | 0.6546 | 42 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2069 | 0.2066 | 39 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.2997 | 0.0539 | 42 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.4510 | 0.0022 | 42 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.0218 | 0.8912 | 42 |
| NPE-2, Upstream | | | | | | | | | |
| NPE-2 | 1.0000 | 0.0000 | 37 | 0.6205 | 0.0001 | 37 | -- | -- | -- |
| SUM | 0.3620 | 0.0277 | 37 | 0.3131 | 0.0592 | 37 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.4781 | 0.0042 | 34 |
| NET | -- | -- | -- | -- | -- | -- | 0.0069 | 0.9677 | 37 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.0990 | 0.5775 | 34 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.2320 | 0.1672 | 37 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.0348 | 0.8381 | 37 |

Appendix Table B-3. Continued.

| Variable 1, count direction, variable 2 | Upstream counts | | | Downstream counts | | | Non-directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | *P* | *N* | r | *P* | *N* | r | *P* | *N* |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.2276 | 0.1755 | 37 |
| NPE-2, Downstream | | | | | | | | | |
| SUM | 0.6583 | 0.0001 | 37 | 0.6922 | 0.0001 | 37 | -- | -- | -- |
| COUNT | -- | -- | -- | -- | -- | -- | 0.7317 | 0.0001 | 34 |
| NET | -- | -- | -- | -- | -- | -- | 0.0049 | 0.9772 | 37 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.1481 | 0.4033 | 34 |
| KCFS | -- | -- | -- | -- | -- | -- | 0.0360 | 0.8325 | 37 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.1458 | 0.3894 | 37 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.0648 | 0.7033 | 37 |
| SUM, Upstream | | | | | | | | | |
| SUM | 1.0000 | 0.0000 | 63 | 0.9440 | 0.0001 | 63 | -- | -- | -- |
| COUNT | | | | | | | 0.8605 | 0.0001 | 59 |
| NET | -- | -- | -- | -- | -- | -- | 0.1572 | 0.2185 | 63 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.2824 | 0.0302 | 59 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.3001 | 0.0169 | 63 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.3807 | 0.0021 | 63 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0151 | 0.9062 | 63 |
| SUM, Downstream | | | | | | | | | |
| COUNT | -- | -- | -- | -- | -- | -- | 0.8380 | 0.0001 | 59 |
| NET | -- | -- | -- | -- | -- | -- | -0.1069 | 0.4043 | 63 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.3770 | 0.0033 | 59 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.2972 | 0.0180 | 63 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.4709 | 0.0001 | 63 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0556 | 0.6651 | 63 |
| COUNT, | | | | | | | | | |
| NET | -- | -- | -- | -- | -- | -- | 0.1137 | 0.3912 | 59 |
| TEMP | -- | -- | -- | -- | -- | -- | 0.4304 | 0.0007 | 59 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.2269 | 0.0840 | 59 |
| NORTH | -- | -- | -- | -- | -- | -- | 0.4545 | 0.0003 | 59 |
| SOUTH | -- | -- | -- | -- | -- | -- | -0.0814 | 0.5402 | 59 |
| NET | | | | | | | | | |
| TEMP | -- | -- | -- | -- | -- | -- | -0.2149 | 0.1022 | 59 |
| KCFS | -- | -- | -- | -- | -- | -- | -0.1498 | 0.2414 | 63 |
| NORTH | -- | -- | -- | -- | -- | -- | -0.1507 | 0.2385 | 63 |
| SOUTH | -- | -- | -- | -- | -- | -- | 0.1789 | 0.1606 | 63 |

[a] *SUM: Total of daily upstream or downstream counts of adult salmonids from all entrances.*
*NET: (SUM of upstream counts - SUM of downstream counts).*
*COUNT: Total daily counts of adult salmonids passing the fish ladder viewing window.*

[b] *KCFS: Mean hourly turbine discharge per day.*
*SOUTH: Mean daily surface water velocity in the south shore collection channel.*
*NORTH: Mean daily surface water velocity in the north powerhouse collection channel.*

[c] *TEMP: Daily forebay water temperature.*

# APPENDIX C

Minimum, Maximum, Median, and Standard Deviation Values for Total Daily Upstream and Downstream Fish Counts at Fishway Entrances by Turbine Operations during Study Periods at Lower Granite Dam

Appendix Table C-1. Minimum, maximum, median, and standard deviation values for total daily upstream and downstream electronic tunnel fish counts by turbine operations at fishway entrances during the spring study period (29 April - 10 June) at Lower Granite Dam, Snake River, 1992.

| Entrance, units operating | *N* | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Median | SD | Min | Max | Median | SD |
| SSE | | | | | | | | | |
| 1-5 | 7 | 7 | 71 | 19.50 | 22.04 | 4 | 37 | 11.00 | 12.02 |
| 1-3,5,6 | 5 | 10 | 55 | 42.64 | 19.49 | 5 | 49 | 32.71 | 19.72 |
| 1-4 | 16 | 9 | 134 | 31.46 | 33.58 | 5 | 211 | 39.50 | 54.38 |
| 1-3 | 27 | 3 | 129 | 40.25 | 28.01 | 3 | 199 | 76.07 | 52.86 |
| FOG-1 | | | | | | | | | |
| 1-5 | 7 | 1 | 47 | 1.71 | 16.96 | 0 | 1 | 0.50 | 0.45 |
| 1-3,5,6 | 5 | 2 | 8 | 5.07 | 3.17 | 0 | 2 | 1.07 | 0.59 |
| 1-4 | 16 | 0 | 20 | 1.67 | 5.31 | 0 | 4 | 0.47 | 1.03 |
| 1-3 | 27 | 1 | 58 | 3.0 | 10.87 | 0 | 7 | 1.78 | 1.89 |
| FOG-4 | | | | | | | | | |
| 1-5 | 7 | 2 | 10 | 4.17 | 2.65 | 0 | 1 | 0.14 | 0.20 |
| 1-3,5,6 | 5 | 1 | 15 | 6.57 | 5.66 | 0 | 2 | 0.57 | 0.73 |
| 1-4 | 16 | 0 | 18 | 3.14 | 4.55 | 0 | 3 | 0.29 | 0.82 |
| 1-3 | 27 | 0 | 24 | 6.83 | 5.36 | 0 | 4 | 1.07 | 0.85 |
| FOG-7 | | | | | | | | | |
| 1-5 | 7 | 5 | 22 | 16.71 | 7.00 | 0 | 1 | 0.40 | 0.38 |
| 1-3,5,6 | 5 | 1 | 3 | 1.21 | 1.02 | 0 | 1 | 0.43 | 0.18 |
| 1-4 | 16 | 1 | 30 | 13.68 | 7.69 | 0 | 5 | 0.42 | 1.26 |
| 1-3 | 27 | 1 | 22 | 5.86 | 4.95 | 0 | 3 | 1.00 | 0.76 |
| FOG-10 | | | | | | | | | |
| 1-5 | 7 | 1 | 10 | 4.71 | 3.20 | 0 | 1 | 0.29 | 0.36 |
| 1-3,5,6 | 5 | 2 | 16 | 13.93 | 6.28 | 0 | 1 | 0.64 | 0.61 |
| 1-4 | 16 | 0 | 15 | 4.92 | 3.53 | 0 | 2 | 0.44 | 0.62 |
| 1-3 | 27 | 0 | 10 | 1.93 | 2.14 | 0 | 5 | 0.50 | 1.05 |
| NPE-1 | | | | | | | | | |
| 1-5 | 4 | 0 | 3 | 0.88 | 1.13 | 1 | 41 | 4.93 | 18.97 |
| 1-3,5,6 | 5 | 2 | 11 | 3.57 | 4.45 | 4 | 17 | 5.29 | 6.90 |
| 1-4 | 12 | 0 | 8 | 3.18 | 2.77 | 2 | 22 | 8.96 | 6.53 |
| 1-3 | 14 | 0 | 15 | 1.79 | 3.73 | 1 | 14 | 4.14 | 3.61 |
| NPE-2 | | | | | | | | | |
| 1-5 | 4 | 0 | 7 | 2.07 | 3.22 | 2 | 26 | 12.00 | 10.55 |
| 1-3,5,6 | 5 | 0 | 13 | 4.64 | 5.10 | 2 | 19 | 12.00 | 6.79 |
| 1-4 | 7 | 0 | 14 | 11.00 | 6.07 | 5 | 22 | 15.75 | 5.87 |
| 1-3 | 21 | 0 | 12 | 3.00 | 3.35 | 1 | 30 | 14.86 | 8.81 |

Appendix Table C-1. Continued.

| Entrance, units operating | N | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Median | SD | Min | Max | Median | SD |
| NPE-3 | | | | | | | | | |
| 1-5 | 6 | 0 | 25 | 1.24 | 9.75 | 0 | 24 | 1.18 | 9.24 |
| 1-4 | 13 | 0 | 23 | 2.14 | 5.96 | 0 | 33 | 1.07 | 8.90 |
| 1-3 | 19 | 0 | 8 | 1.71 | 1.78 | 0 | 7 | 0.86 | 1.83 |
| NSE | | | | | | | | | |
| 1-5 | 7 | 12 | 43 | 27.29 | 10.49 | 5 | 41 | 22.00 | 11.52 |
| 1-3,5,6 | 5 | 20 | 88 | 50.79 | 28.11 | 10 | 58 | 38.86 | 19.98 |
| 1-4 | 16 | 5 | 172 | 29.50 | 40.03 | 4 | 46 | 29.89 | 13.80 |
| 1-3 | 27 | 2 | 115 | 43.86 | 34.89 | 0 | 54 | 24.36 | 14.24 |

Appendix Table C-2. Minimum, maximum, median, and standard deviation values for total daily upstream and downstream video camera counts of adult salmonids by turbine operations at fishway entrances during the summer study period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992.

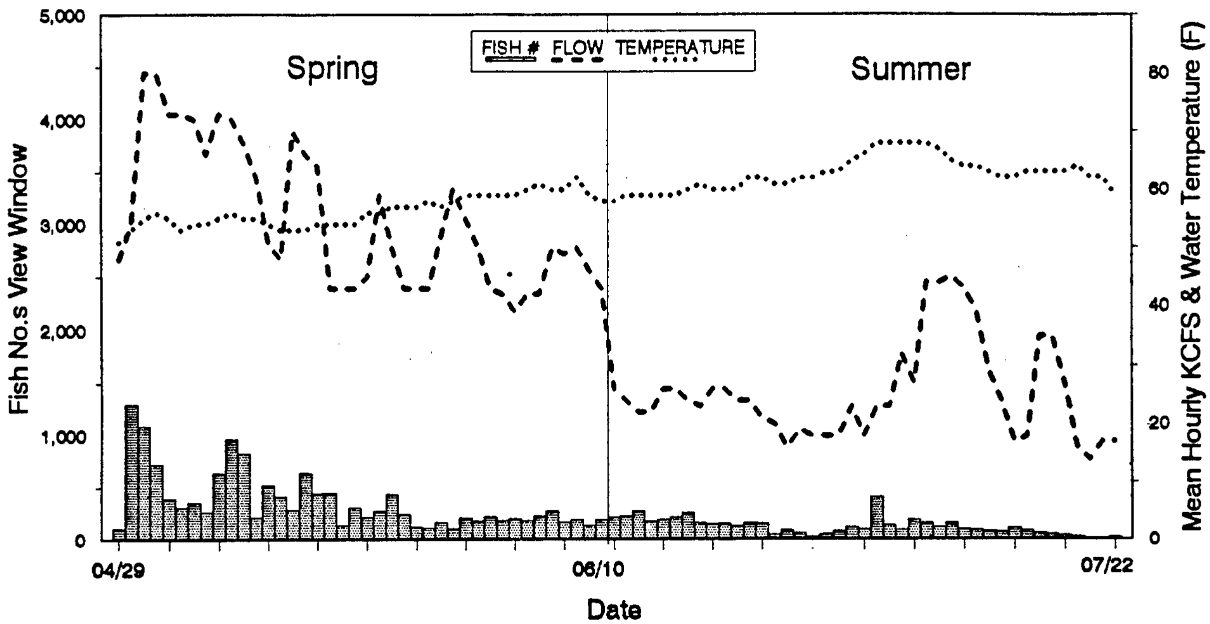
| Entrance, units operating | *N* | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Median | SD | Min | Max | Median | SD |
| SSE | | | | | | | | | |
| 1-3 | 5 | 0 | 13 | 4.29 | 5.35 | 0 | 8 | 2.14 | 3.26 |
| 1-2 | 25 | 0 | 28 | 3.25 | 7.69 | 0 | 24 | 1.68 | 6.16 |
| 1 | 20 | 0 | 30 | 1.27 | 7.52 | 0 | 18 | 2.18 | 6.67 |
| FOG-1 | | | | | | | | | |
| 1-3 | 2 | 0 | 2 | 0.93 | 1.01 | 1 | 1 | 0.68 | 0.15 |
| 1-2 | 6 | 1 | 4 | 2.29 | 1.05 | 0 | 1 | 0.73 | 0.59 |
| 1 | 7 | 0 | 1 | 0.07 | 0.12 | 0 | 3 | 0.54 | 1.07 |
| FOG-4 | | | | | | | | | |
| 1-3 | 3 | 3 | 8 | 4.00 | 2.57 | 0 | 1 | 0.10 | 0.12 |
| 1-2 | 7 | 1 | 6 | 1.25 | 2.32 | 0 | 1 | 0.14 | 0.17 |
| 1 | 8 | 0 | 1 | 0.27 | 0.28 | 0 | 1 | 0.04 | 0.21 |
| FOG-7 | | | | | | | | | |
| 1-2 | 12 | 0 | 1 | 0.11 | 0.26 | 0 | 1 | 0.00 | 0.09 |
| 1 | 5 | 0 | 1 | 0.00 | 0.30 | 0 | 1 | 0.00 | 0.06 |
| NPE-1 | | | | | | | | | |
| 1-3 | 4 | 0 | 1 | 0.08 | 0.14 | 1 | 12 | 1.71 | 5.42 |
| 1-2 | 20 | 0 | 1 | 0.14 | 0.13 | 0 | 18 | 1.83 | 5.30 |
| 1 | 9 | 0 | 1 | 0.00 | 0.44 | 0 | 5 | 1.25 | 1.58 |
| NPE-2 | | | | | | | | | |
| 1-3 | 3 | 0 | 0 | 0.00 | 0.00 | 1 | 2 | 1.80 | 0.75 |
| 1-2 | 15 | 0 | 6 | 0.14 | 1.89 | 1 | 88 | 5.79 | 23.76 |
| 1 | 18 | 0 | 6 | 0.07 | 1.92 | 2 | 85 | 15.22 | 25.99 |
| NSE | | | | | | | | | |
| 1-3 | 5 | 0 | 12 | 7.77 | 4.61 | 0 | 2 | 1.33 | 0.71 |
| 1-2 | 25 | 0 | 27 | 12.26 | 7.54 | 0 | 25 | 1.68 | 6.42 |
| 1 | 20 | 0 | 30 | 8.22 | 10.12 | 0 | 15 | 1.87 | 4.74 |

Appendix Table C-3. Minimum, maximum, median, and standard deviation values for total daily upstream and downstream video camera counts of adult salmonids by turbine operations at fishway entrances during the fall study period (9 September -10 November) at Lower Granite Dam, Snake River, 1992.

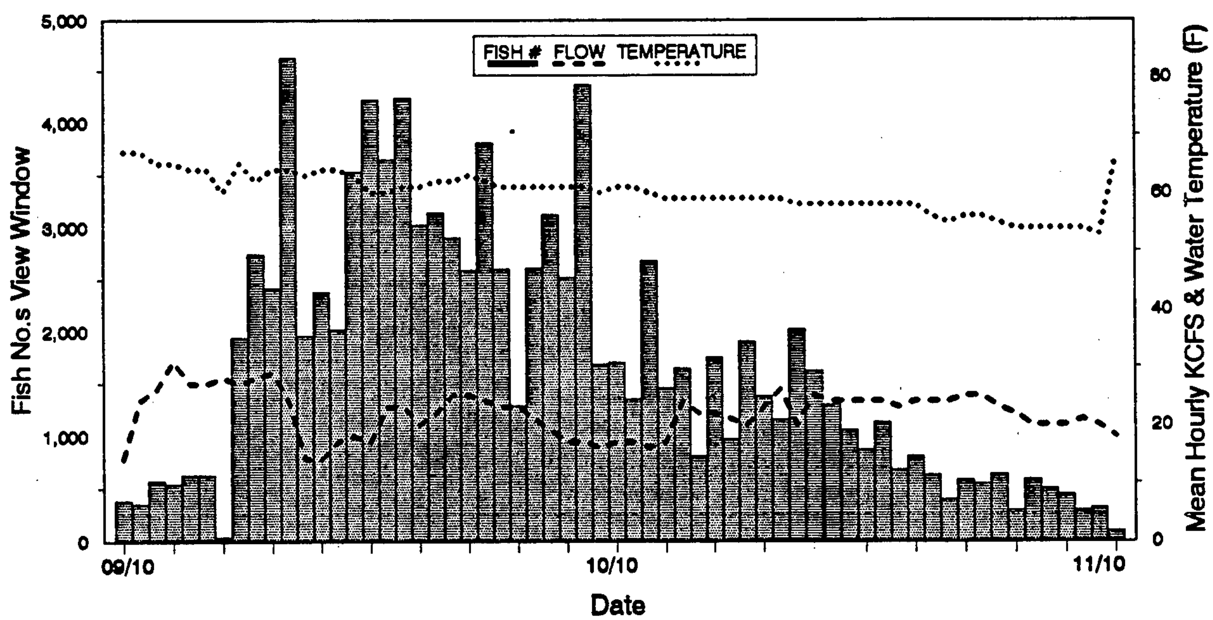
| Entrance, units operating | *N* | Upstream counts Min | Max | Median | SD | Downstream counts Min | Max | Median | SD |
|---|---|---|---|---|---|---|---|---|---|
| SSE | | | | | | | | | |
| 1-2 | 27 | 4 | 258 | 35.20 | 54.13 | 3 | 59 | 16.50 | 16.14 |
| 1,3 | 17 | 3 | 101 | 41.60 | 24.32 | 6 | 61 | 17.60 | 15.27 |
| 1 | 43 | 2 | 348 | 62.00 | 73.77 | 3 | 108 | 39.33 | 26.26 |
| FOG-1 | | | | | | | | | |
| 1-2 | 8 | 3 | 53 | 37.13 | 20.18 | 1 | 5 | 3.69 | 1.53 |
| 1 | 7 | 4 | 21 | 15.20 | 7.11 | 2 | 11 | 3.20 | 3.22 |
| FOG-4 | | | | | | | | | |
| 1,3 | 5 | 0 | 5 | 1.63 | 1.98 | 0 | 2 | 1.00 | 0.68 |
| 1 | 12 | 0 | 6 | 1.80 | 2.20 | 0 | 5 | 1.65 | 1.29 |
| FOG-7 | | | | | | | | | |
| 1-2 | 6 | 0 | 2 | 0.25 | 0.63 | 0 | 1 | 0.33 | 0.25 |
| 1,3 | 12 | 0 | 3 | 0.45 | 0.89 | 0 | 1 | 0.18 | 0.25 |
| 1 | 8 | 0 | 1 | 0.00 | 0.19 | 0 | 1 | 0.00 | 0.04 |
| FOG-10 | | | | | | | | | |
| 1-2 | 13 | 1 | 13 | 3.44 | 3.90 | 1 | 3 | 1.14 | 0.76 |
| 1 | 16 | 1 | 20 | 2.65 | 6.20 | 0 | 7 | 1.10 | 1.79 |
| NPE-1 | | | | | | | | | |
| 1-2 | 18 | 0 | 9 | 0.60 | 2.10 | 0 | 216 | 10.20 | 49.44 |
| 1,3 | 12 | 1 | 14 | 6.00 | 3.99 | 6 | 38 | 9.35 | 12.07 |
| 1 | 22 | 0 | 27 | 0.00 | 6.17 | 1 | 366 | 26.85 | 81.55 |
| NPE-2 | | | | | | | | | |
| 1-2 | 14 | 0 | 8 | 1.69 | 2.54 | 1 | 189 | 12.75 | 51.32 |
| 1,3 | 12 | 0 | 10 | 4.35 | 3.06 | 3 | 41 | 26.25 | 12.88 |
| 1 | 26 | 0 | 10 | 1.10 | 2.99 | 2 | 172 | 12.92 | 40.60 |
| NSE | | | | | | | | | |
| 1-2 | 27 | 1 | 156 | 27.53 | 40.65 | 0 | 224 | 23.58 | 68.34 |
| 1,3 | 17 | 1 | 69 | 24.00 | 20.46 | 3 | 42 | 13.87 | 15.30 |
| 1 | 43 | 1 | 187 | 23.98 | 47.83 | 1 | 267 | 18.58 | 73.76 |

# APPENDIX D

Daily Counts of Adult Salmonids Passing the Fish Viewing Window,
Mean Hourly Powerhouse Discharge, and Daily Water Temperature
during the Spring, Summer, and Fall Study Periods
at Lower Granite Dam, 1992




Appendix Figure D-1. Daily counts of adult salmonids passing the fish viewing window, mean hourly powerhouse discharge, and daily water temperature during the spring (29 April - 10 June) and summer (11 June - 22 July) study periods at Lower Granite Dam, Snake River, 1992.




Appendix Figure D-2. Daily counts of adult salmonids passing the fish viewing window, mean hourly powerhouse discharge, and daily water temperature during the fall study period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992.

# REPORT B

Evaluation of Electronic Impedance Tunnel and Low-Light Underwater Video Camera Technologies as Methods of Evaluating Passage of Adult Salmonids Through Fishway Entrances.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## CONTENTS

# SUMMARY

## Objectives for 1992

During 1992 we planned to (1) determine the accuracy of electronic tunnels in detecting the directional passage of adult salmonids in and out of fishway entrances, (2) assess the proportion of tunnel counts that were salmonids and non-salmonids, (3) determine if electronic tunnels delay fish passage and/or injure fish, and (4) evaluate the feasibility and effectiveness of using underwater video cameras as the primary technology in monitoring adult fish passage.

## Accomplishments in 1992

We accomplished all objectives. In addition, we expanded Objective 4 to include the design, fabrication, and testing of camera frames for the north shore and south shore entrances.

## Findings in 1992

Evaluation of tunnel and video technologies suggest that the differences between upstream and downstream counts generated by both technologies were significant for seasons evaluated (summer and fall) and at most entrances. With count data for various entrances combined, median daily upstream and downstream fish counts were greater from tunnel monitoring in the summer and from video monitoring in the fall. Rank correlation coefficients between counts from the two technologies were usually positively strong and significant. A higher correlation was indicated for upstream counts during both seasons than for downstream counts. Little or no correlation was evident between NET tunnel or video counts and ladder counts in each season.

Salmonids comprised a lower proportion of upstream and downstream electronic tunnel counts during the summer than in the fall. In the summer, proportions of upstream and downstream salmonid counts from tunnels were highest at the combined floating orifice gates (FOGs) and north powerhouse entrances (NPEs), respectively. Non-salmonid species comprised the majority of upstream and downstream tunnel counts at the north shore entrance (NSE) and south shore entrance (SSE). During the fall, a high proportion of upstream salmonid counts were observed at the combined FOGs and SSE. Highest proportions of downstream salmonid counts occurred at the combined FOGs and NPEs. Small fish were counted, more so in the downstream direction than upstream. False tunnel counts were prevalent at most entrances during the summer and fall, but were especially common at the NPEs in the upstream direction. Electronic tunnels located at the FOGs were the most accurate in detecting upstream and downstream passage; NPE tunnels were the most inaccurate. At SSE, tunnel counting accuracy was greater for target fish moving upstream and non-target fish moving downstream.

Of fish moving upstream, collisions with tunnels were not common; but collisions with tunnels were frequently observed for fish moving downstream. Downstream impacts were most prevalent at the combined FOGs and NPEs.

Downstream and upstream approaches were most prevalent at the combined FOGs and NSE.

Camera performance was satisfactory, although several internal, mechanical failures occurred. The effect of lighting conditions on video images varied between seasonal periods and with depth of the camera. The ability to identify fish effectively decreased as turbidities approached the 4-foot level. A total of 12,500 hours of video was taped during the study. Average tape review time was 5.17 hours of tape per hour.

A prototype camera frame was designed and tested at the north shore entrance, but further modifications will be necessary. Two attempts to design a camera frame for the south shore entrance resulted in the ability to effectively video monitor passing fish directly at the entrance.

## INTRODUCTION

Electrical, hydraulic, and mechanical problems, fish behavior, and other water-borne objects affect the performance of electronic tunnels and counters, causing spurious counting (Simpson 1978, Dunkley and Shearer 1982). In the initial design stages of peripheral-electrode tunnels, questions regarding the effects on detection of fallout, re-orientation within the tunnel, and simultaneous passage were asked (Payne et al. 1978). Payne et al. commented that observing fish behavior and passage conditions within tunnels would be beneficial for determining the performance of the peripheral-electrode design. They also recognized the limitations in trying to use this technology to accurately distinguish between adult salmonids and other fish.

The need to validate the efficiency and accuracy of balanced bridge electronic impedance tunnels arose prior to and during the 1991 adult salmonid passage studies at Little Goose and Lower Granite dams. Uncertainty existed as to whether tunnel count data accurately reflected salmonid passage at fishway entrances because of errors believed to be inherent in this type of technology. In addition, an unexpected high number of electronic counts were recorded at all fishway entrances at Lower Granite and Little Goose dams during the latter part of the spring chinook salmon migration in 1991. These counts were believed to be mainly due to large numbers of carp *(Cyprinus carpio)* in the fishways at both projects. The accuracy of electronic tunnels in detecting valid upstream and downstream salmonid counts at fishway entrances remained questionable, hampering attempts to correctly evaluate fallout and entrance use. In addition, methods for calibrating and checking tunnels inseason were limited.

The Oregon Department of Fish and Wildlife (ODFW) believed it was imperative that future tunnel work at any of the lower Snake River dams be accompanied by at least a secondary technology to validate the accuracy of the tunnel counts. Additional drawbacks in the use of electronic tunnels necessitated a reevaluation of this technology. For example, constraints in locating and installing tunnel assemblies at particular entrances forced the placement of tunnel frames in less-than-desirable locations for collecting true passage estimates. Concerns also existed that electronic tunnels placed at fishway entrances could impede passage or injure fish. A review of available alternative technologies revealed that radio telemetry, acoustic imaging, and video imaging were potential secondary technologies. We proposed using video imaging as the secondary technology to verify tunnel counts and perhaps to ultimately replace the tunnel technology in evaluating adult passage. Increased accuracy in entrance-specific passage estimates would improve our ability to determine the effects of powerhouse, spillway, and fishway operations on entrance use and fallout.

ODFW conducted a pilot study in the fall of 1991 to determine if the underwater video technology was a feasible method. Several underwater camera systems were tested to determine which system seemed most appropriate for our purposes. We performed off-site and on-site activities to evaluate imaging in turbid waters, suitable light conditions, optimal camera angle and field of view, effects of high water velocities on camera stability and image resolution, and the ability to identify fish species from taped images. We also investigated modifications needed to improve camera coverage of tunnel

space for maximum observations of fish and what methods were most suitable for efficiently deploying cameras.

Feasibility study results indicated that successful underwater video imaging was possible under the environmental and operating conditions present at the dams. Consequently, a low-light, high-resolution camera system was selected as the most suitable camera to use under the fishway conditions.

In 1992, we intended to validate counts of fish moving through the electronic tunnels at selected fishway entrances at Lower Granite Dam with the chosen underwater video camera system. Data from the taped video images would serve to verify or discredit the directional passage data from electronic tunnels. Although review of video-taped fish passage would provide insight into true numbers and fish species entering and exiting fishway entrances, it would not provide detailed information on detection discrepancies and specific counting errors from electronic tunnels. To ascertain these limitations, we needed to use "real-time" video observations to verify and quantify count efficiencies for various species as they passed through the tunnels, and determine other factors triggering electronic counts. This would allow us to determine if the composition of fish species counted via electronic tunnels was similar to the composition actually passing through the tunnels. This information would assist us in detecting species or directional related counting biases and overall tunnel accuracy.

Additional effort in 1992 would ascertain the feasibility of using only video cameras to document fish passage at the north shore and south shore entrances at Lower Granite Dam. Historically, the narrow dimensions of the north shore and south shore fishway entrances had prohibited the deployment of electronic tunnels. This constraint forced the installation of tunnels in the fishway collection channel upstream from these entrances, a less-than-desirable location for measuring true fishway entry and exits. The logistics of operating multiple camera systems over the long term also needed to be evaluated.

This technology evaluation report includes results from studies conducted at Lower Granite Dam in the lower Snake River. Since the information was obtained in conjunction with our passage evaluation work, a description of the adult passage facilities is presented in that report (**Report A**).

# METHODS

## Equipment

### Electronic Tunnels and Video Cameras

A detailed description of the electronic impedance tunnel and underwater video camera equipment is provided in **Report A**.

### Camera Frames

Our objectives were to construct a camera frame that, when deployed, had the ability to (1) create an environment conducive to video imaging, (2) be

deployed with minimum personnel, without removal of the existing weir gate or assistance from a crane, (3) support two (NSE-1) or three (SSE-1) cameras with adjustments for the imaging angle and upstream or downstream orientations, (4) rise and fall with the existing weir gate such that operating criteria would not be compromised, and (5) not impede fish passage, injure fish, or significantly alter flow conditions.

We conducted site-specific evaluations at NSE-1 and SSE-1 during April 1992 to assist in developing concepts for frames that could be used for camera deployment. We identified potential limitations based upon entrance dimensions and operating conditions. We consulted U.S. Army Corps of Engineers personnel and reviewed current fishway operating criteria to determine seasonal variations in entrance operations. Concerns included daily and seasonal variations in weir gate depth, operations and dependability of weir gate hoists, and restrictions on access to weir gate controls. Additionally, we contacted and consulted with personnel from the metal shop at the University of Idaho.

## Data Collection

### Electronic Tunnel and Video Camera Counts

A detailed description of data collection methods for electronic impedance tunnels and underwater video cameras is provided in **Report A**. We used the number of upstream and downstream salmonid fish observations or counts to ascertain entrance use and fallout, respectively. We also documented the number of salmonids that impacted the tunnel from the upstream or downstream direction and the number of salmonid species that approached, but did not enter, the tunnel from either direction. We noted such factors as picture quality, lighting, and visibility.

### Camera Logistics

To determine the efficacy of using underwater video cameras as a method of monitoring fish passage at fishway entrances, we attempted to identify factors that could limit their feasibility. During the course of our research, we were interested in collecting information on use and logistics pertaining to camera performance, recording process, and tape review time. We also wanted to identify and describe the ability of video cameras to withstand the environmental conditions present within the fishway and at the fishway entrances and whether their presence influenced passage. Additionally, we needed to determine and document the amount of repairs that cameras and associated recording equipment needed during the field season. The tape recording and review process was of particular concern because we believed it to be the most labor intensive portion of our research. We were also interested in describing the operational performance of time-lapse VCRs, the number of hours of tape that was recorded, the time to review tape, the quantity of tape needed, and factors influencing tape review time.

## Data Analysis

### Count Comparisons

Prior to any data analysis, we determined the proportion of unidentifiable fish observations from video images that could be target fish species (*see* **Report A**). For tunnel and video comparisons, we paired the data on an hour-by-hour basis. If data from either technology in the pair was missing, the entire observation was deleted from the data set. Therefore, all paired data only contained observations from both the tunnels and cameras. To determine daily upstream and downstream passage totals from monitored tunnels, we summed the hourly counts from each technology for each day.

We computed daily median estimates and the median difference between daily tunnel and video estimates, and associated minimum, maximum, and standard deviation values, for both upstream and downstream counts by season (summer + fall), entrance, and entrances combined.

Non-parametric procedures were used for statistical analyses since the data did not consistently meet the assumptions of normality and equal variances. In all tests, we chose as our significance level a P value of $< 0.05$. All testing was completed using procedures in the SAS program for personal computers (SAS Institute Inc. 1990). A non-parametric paired-difference t-test (Wilcoxon Signed Rank test) was used to determine whether the median difference in tunnel and video upstream or downstream counts was statistically different than zero.

To determine the degree of association between tunnel and video counts, we computed a rank correlation coefficient using the Spearman Rank test. Hourly paired tunnel and video counts were summed for the day, and daily values were used to derive rank correlation coefficients for each entrance and entrances combined.

To determine whether the tunnel counts or video counts reflected true passage by the project, we compared numbers of fish using fishway entrances to numbers of fish passing the fish viewing window in the ladder. We expanded the tunnel and video data to derive estimated daily upstream and downstream passage totals (*see* **Report A**). Once daily upstream and downstream estimates were computed, we calculated daily net (NET) upstream passage through the tunnels:

$$\text{NET} = \text{SUM UP} - \text{SUM DOWN}$$

where

SUM UP = sum of all upstream counts for all entrances for a given day, and

SUM DOWN = sum of all downstream counts for all entrances for a given day.

We computed a rank correlation coefficient to determine if daily numbers of fish using fishway entrances (NET passage) were associated with numbers of

fish passing the fish viewing window for three seasonal periods (spring, summer, fall) using tunnel data, and for two seasonal periods (summer + fall) using video data. These seasonal time periods corresponded to migration periods of spring and summer chinook salmon and summer steelhead, respectively.

We also performed a non-parametric paired-difference test (Wilcoxon Signed Rank test) to determine if NET passage estimates from the tunnels and cameras were significantly different from fish ladder counts. Tests were performed for each seasonal time period.

## Tunnel Accuracy

We used underwater video cameras to observe fish species as they passed through electronic impedance tunnels during the summer and fall study periods ("real-time" observations). To determine which electronic tunnels would be observed each day, we randomly selected tunnels from the pool of tunnels that were currently being monitored with underwater video cameras (*see* **Report A**). We randomly selected tunnels at SSE and NSE that were representative of high activity to ensure that fish would be observed. We monitored up to 5 selected tunnels each day at various entrances for approximately 10 minutes per tunnel. Viewing times were randomly selected for each day.

We attached a black and white monitor to the video-out jack on the VCR. This allowed us to monitor fish activity within the tunnel without interrupting the video recording process. Personnel would concurrently observe the video monitor and electronic fish counter and record fish passage events as they occurred. We defined an event as upstream or downstream passage of an individual fish through an electronic tunnel, or a count registered by the counter when no fish passage was observed (false count). We attempted to distinguish between species and sizes of fish passing the tunnel. We categorized fish passages as either (1) "target" (adult chinook or steelhead), (2) "non-target" (carp), (3) "unknown" (large enough to be a target or non-target fish, but unable to identify to species), (4) "small" (smaller than target or non-target species and theoretically not of sufficient girth to register an electronic tunnel count; e.g. sucker, shad, peamouth) and, (5) "false" (count registered by the counter when no fish passage observed).

For purposes of analysis, we subjectively grouped entrances according to similar characteristics and/or locations along the fishway. We considered SSE and NSE to be individual entrances, grouped all FOGs (1, 4, 7, and 10), and grouped NPEs (1 and 2).

To determine the species composition of upstream and downstream electronic tunnel counts registered at each entrance or entrance grouping during each study period, we calculated percent composition for target, non-target, unknown, small, and false count event types as:

$$(\text{No. counted} \;/\; \text{sum no. counted}) \times 100$$

where

No. counted = the number of upstream or downstream electronic tunnel counts registered per event type at a given entrance for a given period and,

Sum no. counted = the sum of upstream or downstream electronic tunnel counts registered for all event types at a given entrance for a given period.

To determine the composition of fish species actually passing upstream or downstream through electronic tunnels, we calculated percent composition for target, non-target, unknown, and small event types as:

$$(\text{No. observations} / \text{sum no. observations}) \times 100$$

where

No. observations = the total number of fish in a given event type observed passing upstream or downstream through electronic tunnels at a given entrance for a given period and,

Sum no. observations = the sum of the number of fish in all event types observed passing upstream or downstream through electronic tunnels at a given entrance for a given period.

To determine the absolute accuracy of electronic tunnels in detecting directional passage of target and non-target fish species, we calculated accuracy for upstream and downstream counts as:

$$\text{No. counted} / \text{no. observations}$$

where

No. counted = the number of upstream or downstream electronic tunnel counts registered per event type at a given entrance for a given period and,

No. observations = the total number of fish in a given event type observed, with video, passing upstream or downstream through electronic tunnels at a given entrance for a given period.

### Delay and Injury

To determine the extent to which electronic tunnels delayed passage or injured fish, we computed an approach index and an impact index, respectively. These indices were derived from observations with video cameras at specific tunnel locations during the summer and fall seasons. Downstream and upstream approaches were not differentiated although impacts were. The approach index was determined as

$$\frac{\text{No. approaches}}{\text{Total passage}}$$

where

No. approaches = the number of fish that approached, but did not enter the tunnel from either the downstream or upstream direction, and

Total passage = the total number of fish passing through the tunnel in both the downstream and upstream directions.

Adult salmonids impacting on or within the tunnels were documented with video and categorized as upstream or downstream impacts. The number of impacts was not part of the passage total. The impact index was determined as

$$\frac{\text{No. upstream (downstream) impacts}}{\text{Total upstream (downstream) passage}}$$

where

No. upstream (downstream) impacts = the number of fish impacting on or within the tunnel in the upstream (or downstream) direction, and

Total upstream (downstream) passage = the total number of fish passing through the tunnel in the upstream (or downstream) direction.

## RESULTS

### Count Comparisons

For entrances combined, median daily upstream and downstream counts were greater from tunnel monitoring in the summer and from video monitoring in the fall (Table 1). In the summer, median upstream tunnel counts were 4.2 times greater than video counts; median downstream counts were 6.1 times greater. In the fall, median upstream video counts were 2.0 times greater than tunnel counts; median downstream counts were 1.4 times greater. The average difference between the two counts for both seasons and passage directions was significantly different than zero ($P < 0.0001$).

The floating orifice gates and monitored tunnels representing the north shore and south shore entrances contributed most to the larger number of upstream counts from summer tunnel monitoring. (Table 1). The median difference between the counts was significantly different than zero for all weeks in the summer period (Table 4). The north powerhouse entrances showed little difference in median upstream counts between the two technologies, and at times video counts were larger than tunnel counts (Tables 1 and 2). For most weeks, the median difference between the upstream counts at NPE-1 and/or NPE-2 was not significantly different than zero (Table 4).

The monitored tunnels at the south shore, north shore, and north Powerhouse 2 entrances revealed the greatest downstream activity through summer tunnel monitoring; NPE-1 and the floating orifice gate entrances revealed the least (Table 1). In contrast, median downstream counts at NPE-2 were greater with the video monitoring than with the tunnel, and considerably less at the south shore, north shore, and floating orifice gate entrances (Table 1). The median difference in daily downstream counts from tunnel and video monitoring was usually significantly different than zero for most

Table 1. Daily median, minimum, maximum, and standard deviation values for upstream and downstream fish counts at monitored fishway entrances and entrances combined, as determined from electronic tunnels and video cameras, during the summer (11 June - 22 July) and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

| Season, tech, entrance | *N* (days) | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Median | Min | Max | SD | Median | Min | Max | SD |
| Summer | | | | | | | | | |
| Tunnel, | | | | | | | | | |
| All | 201 | 21.00 | 0 | 1155 | 234.33 | 46.00 | 0 | 1035 | 160.01 |
| SSE | 47 | 120.00 | 2 | 751 | 186.13 | 166.00 | 2 | 1035 | 246.10 |
| FOG | 45 | 19.00 | 0 | 197 | 42.18 | 13.00 | 0 | 331 | 77.51 |
| NPE1 | 31 | 1.00 | 0 | 15 | 3.83 | 9.00 | 1 | 232 | 59.37 |
| NPE2 | 31 | 2.00 | 0 | 35 | 6.64 | 38.00 | 0 | 253 | 69.55 |
| NSE | 47 | 344.00 | 3 | 1155 | 335.70 | 67.00 | 0 | 205 | 68.29 |
| Video, | | | | | | | | | |
| All | 201 | 5.00 | 0 | 152 | 30.72 | 7.53 | 0 | 595 | 80.84 |
| SSE | 47 | 11.00 | 0 | 127 | 28.65 | 9.27 | 0 | 93 | 23.32 |
| FOG | 45 | 4.00 | 0 | 87 | 21.27 | 2.00 | 0 | 19 | 5.13 |
| NPE1 | 31 | 0.00 | 0 | 2 | 0.86 | 8.00 | 0 | 125 | 33.06 |
| NPE2 | 31 | 1.00 | 0 | 38 | 9.97 | 40.50 | 1 | 595 | 176.79 |
| NSE | 47 | 48.27 | 1 | 152 | 40.98 | 6.00 | 0 | 83 | 20.12 |
| Fall | | | | | | | | | |
| Tunnel, | | | | | | | | | |
| All | 264 | 13.00 | 0 | 385 | 60.13 | 25.00 | 0 | 1035 | 110.65 |
| SSE | 63 | 27.00 | 1 | 385 | 76.90 | 58.00 | 2 | 1035 | 116.68 |
| FOG | 62 | 6.00 | 0 | 222 | 54.09 | 4.00 | 0 | 66 | 14.85 |
| NPE1 | 41 | 3.00 | 0 | 205 | 33.28 | 36.00 | 2 | 457 | 87.19 |
| NPE2 | 35 | 5.00 | 0 | 19 | 6.34 | 34.00 | 1 | 351 | 80.99 |
| NSE | 63 | 49.00 | 0 | 262 | 62.25 | 25.00 | 0 | 331 | 58.95 |
| Video, | | | | | | | | | |
| All | 264 | 25.50 | 0 | 992 | 162.85 | 36.00 | 0 | 863 | 139.55 |
| SSE | 63 | 138.00 | 7 | 992 | 212.44 | 82.00 | 8 | 382 | 88.67 |
| FOG | 62 | 14.00 | 0 | 483 | 103.63 | 10.00 | 0 | 45 | 12.41 |
| NPE1 | 41 | 2.00 | 0 | 45 | 11.91 | 48.00 | 2 | 771 | 151.66 |
| NPE2 | 35 | 6.00 | 0 | 33 | 9.53 | 44.00 | 5 | 584 | 135.73 |
| NSE | 63 | 54.00 | 1 | 827 | 175.22 | 45.00 | 1 | 863 | 204.00 |

entrances; non-significant differences were usually noted at NPE-1 and NPE-2, except during Weeks 9 and 10 (Tables 2 and 4).

Table 2. Median difference between daily upstream and downstream tunnel and video counts (tunnel-video), with minimum, maximum, and standard deviation values, at monitored fishway entrances during the summer period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992.

| | | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| Week, entrance | *N* (days) | Median | Min | Max | SD | Median | Min | Max | SD |
| Week 7, | | | | | | | | | |
| SSE | 7 | 116.00 | 76 | 392 | 109.37 | 143.00 | 116 | 308 | 65.76 |
| FOG | 7 | 9.00 | 0 | 170 | 61.22 | 16.00 | 2 | 203 | 72.88 |
| NPE1 | 7 | 4.00 | 0 | 14 | 5.97 | 5.00 | -3 | 9 | 4.61 |
| NPE2 | 7 | 1.00 | -1 | 29 | 10.64 | 3.00 | -19 | 115 | 46.95 |
| NSE | 7 | 340.84 | 76 | 1068 | 324.20 | 137.00 | 43 | 187 | 59.51 |
| Week 8, | | | | | | | | | |
| SSE | 8 | 49.92 | 2 | 172 | 54.06 | 102.00 | 0 | 281 | 86.54 |
| FOG | 8 | 8.00 | 0 | 13 | 5.26 | 6.00 | 1 | 14 | 4.52 |
| NPE1 | 8 | 0.50 | -1 | 3 | 1.28 | -2.00 | -11 | 4 | 5.71 |
| NSE | 8 | 322.98 | 73 | 562 | 161.42 | 90.00 | 6 | 162 | 52.62 |
| Week 9, | | | | | | | | | |
| SSE | 8 | 365.27 | 124 | 630 | 175.00 | 579.53 | 133 | 950 | 262.23 |
| FOG | 6 | 40.00 | 5 | 81 | 29.89 | 124.55 | 67 | 179 | 47.69 |
| NPE2 | 8 | -7.50 | -28 | -3 | 10.21 | -178.49 | -477 | 0 | 168.00 |
| NSE | 8 | 613.07 | 15 | 1027 | 299.25 | 89.37 | 5 | 157 | 48.23 |
| Week 10, | | | | | | | | | |
| SSE | 8 | 112.00 | 3 | 697 | 218.20 | 307.65 | 9 | 709 | 209.52 |
| FOG | 8 | 17.50 | -2 | 171 | 56.42 | 90.30 | 0 | 312 | 109.12 |
| NPE1 | 8 | 0.00 | -1 | 2 | 0.89 | 14.36 | -1 | 172 | 61.57 |
| NSE | 8 | 605.48 | 39 | 878 | 291.48 | 88.50 | 2 | 138 | 42.70 |
| Week 11, | | | | | | | | | |
| SSE | 8 | 35.50 | 2 | 56 | 19.10 | 124.50 | 39 | 179 | 47.31 |
| FOG | 8 | -13.75 | -41 | 0 | 14.62 | 4.00 | -3 | 10 | 5.37 |
| NPE1 | 8 | -0.50 | -2 | 1 | 0.93 | 1.00 | -14 | 16 | 8.78 |
| NPE2 | 8 | 0.00 | 0 | 2 | 0.71 | -7.46 | -83 | 13 | 32.70 |
| NSE | 8 | 38.00 | 9 | 197 | 68.65 | 3.50 | -1 | 27 | 8.94 |
| Week 12, | | | | | | | | | |
| SSE | 8 | 50.50 | -3 | 179 | 71.98 | 118.00 | -5 | 503 | 191.96 |
| FOG | 8 | 13.00 | -5 | 61 | 24.86 | 7.50 | 3 | 55 | 17.10 |
| NPE2 | 8 | 0.50 | -2 | 2 | 1.49 | 8.91 | -16 | 22 | 13.52 |
| NSE | 8 | 10.00 | 1 | 32 | 12.00 | 3.00 | -4 | 5 | 3.11 |

During the fall period, upstream counts from the south shore, north shore, and floating orifice gate entrances contributed the most to the larger number of upstream counts from video monitoring (Table 1). Using video cameras, median fish per day was greatest at SSE and was far greater than tunnel counts. In many cases, whenever upstream video counts were greater than tunnel counts, the median difference was significantly different than zero (Tables 3 and 4). If upstream tunnel counts were larger than video counts, the median difference was usually not significant.

Greatest downstream activity revealed in fall video monitoring was at NPE-1, NPE-2, SSE, and NSE (Table 1). For weeks monitored, the median difference in tunnel and video counts at these entrances was usually significantly different than zero (Tables 3 and 4). The median difference in tunnel and video downstream counts at the FOGs in the fall was usually small and insignificant.

Table 3. Median difference between daily upstream and downstream tunnel and video counts (tunnel-video), with minimum, maximum, and standard deviation values, at monitored fishway entrances during the fall period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992.

| | | Upstream counts | | | | Downstream counts | | | |
|---|---|---|---|---|---|---|---|---|---|
| Week, entrance | *N* (days) | Median | Min | Max | SD | Median | Min | Max | SD |
| Week 1, | | | | | | | | | |
| SSE | 7 | -12.00 | -51 | 187 | 79.73 | 11.00 | -1 | 459 | 167.73 |
| FOG | 7 | -12.00 | -23 | -1 | 8.32 | -3.00 | -7 | -2 | 2.00 |
| NPE1 | 7 | 2.00 | -2 | 5 | 2.54 | 26.00 | -10 | 104 | 38.93 |
| NPE2 | 7 | -3.00 | -6 | 3 | 3.36 | -16.00 | -65 | 1 | 23.58 |
| NSE | 7 | -6.17 | -35 | 31 | 23.53 | -13.00 | -75 | 5 | 26.59 |
| Week 2, | | | | | | | | | |
| SSE | 7 | -342.00 | -931 | -76 | 301.84 | -44.00 | -66 | 124 | 82.80 |
| FOG | 7 | -10.00 | -64 | -3 | 27.36 | -3.50 | -17 | 5 | 6.88 |
| NPE1 | 5 | 1.00 | -22 | 7 | 11.24 | -104.00 | -491 | -45 | 214.04 |
| NSE | 7 | -274.00 | -521 | -73 | 150.68 | -531.00 | -708 | -160 | 206.71 |
| Week 3, | | | | | | | | | |
| SSE | 6 | -302.00 | -665 | 62 | 241.86 | 266.00 | -111 | 729 | 346.91 |
| FOG | 6 | -24.50 | -144 | 10 | 54.64 | 0.50 | -6 | 26 | 11.48 |
| NPE2 | 6 | -5.50 | -12 | 12 | 8.99 | -66.00 | -272 | 3 | 116.15 |
| NSE | 6 | -244.50 | -603 | -11 | 232.35 | -175.96 | -397 | -12 | 124.61 |
| Week 4, | | | | | | | | | |
| SSE | 8 | -105.00 | -277 | 92 | 121.44 | 73.86 | -46 | 356 | 121.19 |
| FOG | 7 | -50.00 | -273 | 8 | 121.21 | 6.00 | 0 | 26 | 8.52 |
| NPE1 | 8 | -1.00 | -6 | 4 | 2.83 | -50.93 | -131 | -4 | 41.25 |
| NSE | 8 | -73.78 | -136 | 1 | 46.05 | -82.50 | -168 | 3 | 50.22 |

Table 3. Continued.

| Week, entrance | N (days) | Upstream counts Median | Min | Max | SD | Downstream counts Median | Min | Max | SD |
|---|---|---|---|---|---|---|---|---|---|
| Week 5, | | | | | | | | | |
| SSE | 5 | -189.00 | -420 | -112 | 116.20 | -140.47 | -200 | -111 | 33.92 |
| FOG | 5 | -6.00 | -40 | -3 | 15.35 | -11.00 | -35 | 3 | 14.95 |
| NPE1 | 5 | 0.00 | 0 | 1 | 0.55 | -47.00 | -100 | -18 | 32.79 |
| NSE | 5 | -2.86 | -35 | 49 | 32.16 | -3.00 | -37 | 6 | 17.10 |
| Week 6, | | | | | | | | | |
| SSE | 7 | -91.00 | -192 | -46 | 61.65 | -64.00 | -142 | -16 | 44.71 |
| FOG | 7 | -23.00 | -50 | -8 | 14.28 | -6.00 | -19 | -2 | 5.88 |
| NPE2 | 7 | 0.00 | -26 | 9 | 11.22 | -22.00 | -43 | 32 | 27.71 |
| NSE | 7 | -10.00 | -73 | 53 | 41.66 | -15.00 | -39 | 4 | 14.94 |
| Week 7, | | | | | | | | | |
| SSE | 7 | -100.00 | -224 | -36 | 68.19 | -35.00 | -104 | -15 | 32.14 |
| FOG | 7 | -2.00 | -17 | 2 | 6.90 | -1.00 | -4 | 2 | 1.98 |
| NPE1 | 7 | -20.00 | -30 | -7 | 8.04 | -16.00 | -53 | 2 | 23.19 |
| NPE2 | 7 | -3.00 | -24 | 1 | 8.81 | -12.00 | -33 | 22 | 20.06 |
| NSE | 7 | -32.00 | -61 | -23 | 13.53 | -40.00 | -79 | 1 | 24.12 |
| Week 8, | | | | | | | | | |
| SSE | 7 | -59.00 | -82 | -17 | 20.85 | -29.00 | -56 | -11 | 15.09 |
| FOG | 7 | -1.00 | -8 | 0 | 2.94 | 0.00 | -1 | 1 | 0.82 |
| NPE1 | 7 | 30.00 | -1 | 197 | 69.41 | 27.00 | -28 | 428 | 157.97 |
| NSE | 7 | -5.00 | -16 | 2 | 7.38 | -8.00 | -20 | -1 | 6.51 |
| Week 9, | | | | | | | | | |
| SSE | 7 | -29.00 | -266 | -13 | 94.14 | -42.00 | -220 | -18 | 71.99 |
| FOG | 7 | 0.00 | -1 | 0 | 0.49 | 0.00 | 0 | 1 | 0.38 |
| NPE2 | 7 | -1.00 | -4 | 1 | 1.57 | -3.00 | -14 | 6 | 7.08 |
| NSE | 7 | -1.00 | -9 | 2 | 3.40 | -4.00 | -7 | 0 | 2.14 |

Table 4. Signed rank and probability values from non-parametric paired-difference t-tests (Wilcoxon Signed Rank test) comparing differences between daily tunnel and video fish counts at monitored entrances during the summer (11 June - 22 July) and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

| | | Up counts | | Down counts | |
|---|---|---|---|---|---|
| Season, week, entrance | *N* (days) | Signed rank statistic | *P - value* | Signed rank statistic | *P - value* |
| Summer | | | | | |
| Week 7, | | | | | |
| SSE | 7 | 14.0 | 0.0156 | 14.0 | 0.0156 |
| FOG | 7 | 10.5 | 0.0313 | 14.0 | 0.0156 |
| NPE1 | 7 | 7.5 | 0.0625 | 9.5 | 0.1250 |
| NPE2 | 7 | 8.5 | 0.1250 | 7.0 | 0.2969 |
| NSE | 7 | 14.0 | 0.0156 | 14.0 | 0.0156 |
| Week 8, | | | | | |
| SSE | 8 | 18.0 | 0.0078 | 14.0 | 0.0156 |
| FOG | 8 | 10.5 | 0.0313 | 18.0 | 0.0078 |
| NPE1 | 8 | 5.5 | 0.2500 | -8.0 | 0.2969 |
| NSE | 8 | 18.0 | 0.0078 | 18.0 | 0.0078 |
| Week 9, | | | | | |
| SSE | 8 | 18.0 | 0.0078 | 18.0 | 0.0078 |
| FOG | 6 | 10.5 | 0.0313 | 10.5 | 0.0313 |
| NPE2 | 8 | -18.0 | 0.0078 | -18.0 | 0.0078 |
| NSE | 8 | 18.0 | 0.0078 | 18.0 | 0.0078 |
| Week 10, | | | | | |
| SSE | 8 | 18.0 | 0.0078 | 18.0 | 0.0078 |
| FOG | 8 | 16.0 | 0.0234 | 14.0 | 0.0156 |
| NPE1 | 8 | 1.5 | 0.7500 | 17.0 | 0.0156 |
| NSE | 8 | 18.0 | 0.0078 | 18.0 | 0.0078 |
| Week 11, | | | | | |
| SSE | 8 | 18.0 | 0.0078 | 18.0 | 0.0078 |
| FOG | 8 | -14.0 | 0.0156 | 9.0 | 0.1406 |
| NPE1 | 8 | -5.0 | 0.3125 | 1.0 | 0.9062 |
| NPE2 | 8 | 0.5 | 1.0000 | -10.0 | 0.1953 |
| NSE | 8 | 18.0 | 0.0078 | 13.0 | 0.0313 |
| Week 12, | | | | | |
| SSE | 8 | 17.0 | 0.0156 | 17.0 | 0.0156 |
| FOG | 8 | 15.5 | 0.0313 | 18.0 | 0.0078 |
| NPE2 | 8 | 3.0 | 0.7656 | 8.0 | 0.3125 |
| NSE | 8 | 18.0 | 0.0078 | 13.5 | 0.0703 |

Table 4. Continued.

| Season, week, entrance | N (days) | Up counts | | Down counts | |
|---|---|---|---|---|---|
| | | Signed rank statistic | *P - value* | Signed rank statistic | *P - value* |
| Fall | | | | | |
| Week 1, | | | | | |
| SSE | 7 | -6.0 | 0.3594 | 12.5 | 0.0469 |
| FOG | 7 | -14.0 | 0.0156 | -14.0 | 0.0156 |
| NPE1 | 7 | 10.0 | 0.1250 | 11.0 | 0.0781 |
| NPE2 | 7 | -9.5 | 0.1250 | -13.0 | 0.0313 |
| NSE | 7 | -2.0 | 0.8125 | -13.0 | 0.0313 |
| Week 2, | | | | | |
| SSE | 7 | -14.0 | 0.0156 | 4.0 | 0.5781 |
| FOG | 7 | -14.0 | 0.0156 | -8.5 | 0.1719 |
| NPE1 | 5 | 1.0 | 0.8750 | -7.5 | 0.0625 |
| NSE | 7 | -14.0 | 0.0156 | -14.0 | 0.0156 |
| Week 3, | | | | | |
| SSE | 6 | -9.5 | 0.0625 | 7.5 | 0.1562 |
| FOG | 6 | -8.5 | 0.0937 | 2.5 | 0.6250 |
| NPE2 | 6 | -3.5 | 0.5937 | -9.5 | 0.0625 |
| NSE | 6 | -10.5 | 0.0313 | -10.5 | 0.0313 |
| Week 4, | | | | | |
| SSE | 8 | -11.5 | 0.0625 | 16.0 | 0.0234 |
| FOG | 7 | -12.0 | 0.0469 | 10.5 | 0.0313 |
| NPE1 | 8 | -5.5 | 0.2812 | -18.0 | 0.0078 |
| NSE | 8 | -17.0 | 0.0156 | -17.0 | 0.0156 |
| Week 5, | | | | | |
| SSE | 5 | -7.5 | 0.0625 | -7.5 | 0.0625 |
| FOG | 5 | -7.5 | 0.0625 | -4.0 | 0.2500 |
| NPE1 | 5 | -1.5 | 0.5000 | -7.5 | 0.0625 |
| NSE | 5 | -0.5 | 1.0000 | -8.0 | 0.4375 |
| Week 6, | | | | | |
| SSE | 7 | -14.0 | 0.0156 | -14.0 | 0.0156 |
| FOG | 7 | -14.0 | 0.0156 | -14.0 | 0.0156 |
| NPE2 | 7 | -0.5 | 1.0000 | -8.0 | 0.2187 |
| NSE | 7 | -5.0 | 0.4687 | -12.0 | 0.0469 |
| Week 7, | | | | | |
| SSE | 7 | -14.0 | 0.0156 | -14.0 | 0.0156 |
| FOG | 7 | -7.0 | 0.1875 | -7.0 | 0.5312 |
| NPE1 | 7 | -14.0 | 0.0156 | -11.0 | 0.0781 |
| NPE2 | 7 | -9.0 | 0.0937 | -6.0 | 0.3750 |
| NSE | 7 | -14.0 | 0.0156 | -13.0 | 0.0313 |

Table 4. Continued.

| Season, week, entrance | *N* (days) | Up counts: Signed rank statistic | Up counts: *P - value* | Down counts: Signed rank statistic | Down counts: *P - value* |
|---|---|---|---|---|---|
| Week 8, | | | | | |
| SSE | 7 | -14.0 | 0.0156 | -14.0 | 0.0156 |
| FOG | 7 | -10.5 | 0.0313 | 0.0 | 1.0000 |
| NPE1 | 7 | 12.5 | 0.0469 | 9.0 | 0.1562 |
| NSE | 7 | -13.0 | 0.0313 | -14.0 | 0.0156 |
| Week 9, | | | | | |
| SSE | 7 | -14.0 | 0.0156 | -14.0 | 0.0156 |
| FOG | 7 | -1.5 | 0.5000 | 0.5 | 1.0000 |
| NPE2 | 7 | -8.0 | 0.1562 | -2.5 | 0.7500 |
| NSE | 7 | -10.0 | 0.1250 | -10.5 | 0.0313 |

Although median differences in daily tunnel and video counts on a weekly basis were usually significant for most entrances, the rank correlations between counts from the two technologies were positively strong and significant (Figure 1). A stronger correlation was indicated for upstream counts during both seasons than for downstream counts. The highest rank correlation coefficient was achieved for upstream counts during the summer ($r = 0.85$).

During the summer, entrance-specific rank correlations for upstream counts between the two technologies were strongest and significant at NSE and SSE, and weakest and non-significant at NPE-1 (Figure 2). The association between tunnel and video counts at NPE-2 and combined FOGs were not as strong, but they were significantly different than zero. Rank correlations for downstream counts at specific entrances were significantly strong at NSE, NPE-1 and NPE-2. Although significantly different from zero, rank correlations were not as strong at the combined FOGs and SSE.

During the fall period, the association between tunnel and video upstream counts was strongest at the combined FOGs, NSE, NPE-1, and NPE-2, and weakest at SSE (Figure 3). Rank correlations for downstream counts were strongest at NSE, combined FOGs, and NPE-2. Weaker associations were suggested for SSE and NPE-1.

NET tunnel counts were weakly, but significantly, correlated with ladder counts during the spring period, but not in the summer or fall (Figure 4). A very weak, but significant, correlation existed between NET video counts and ladder counts during the summer; no strong or significant correlation was evident for the fall period (Figure 5).

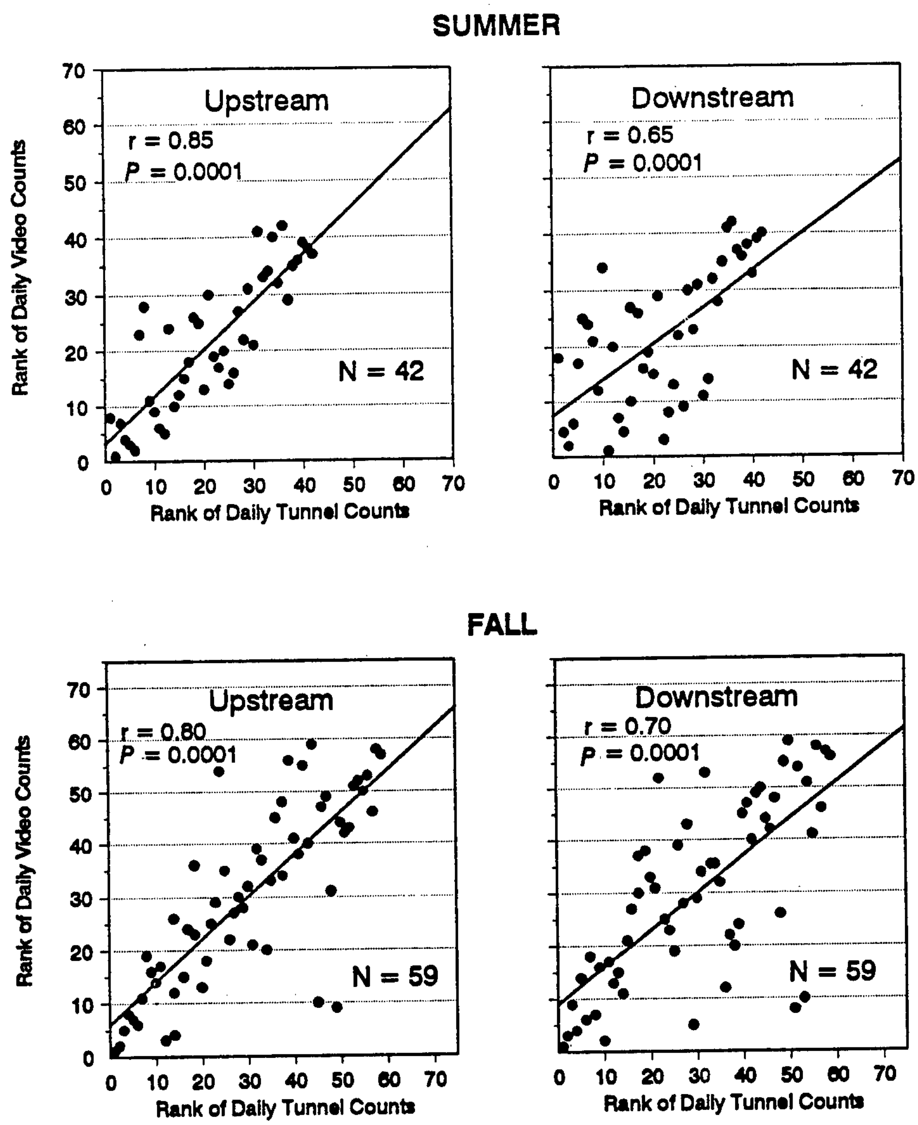


Figure 1. Correlations between ranks of total daily upstream and downstream electronic tunnel and video counts during the summer (11 June - 22 July) and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992.

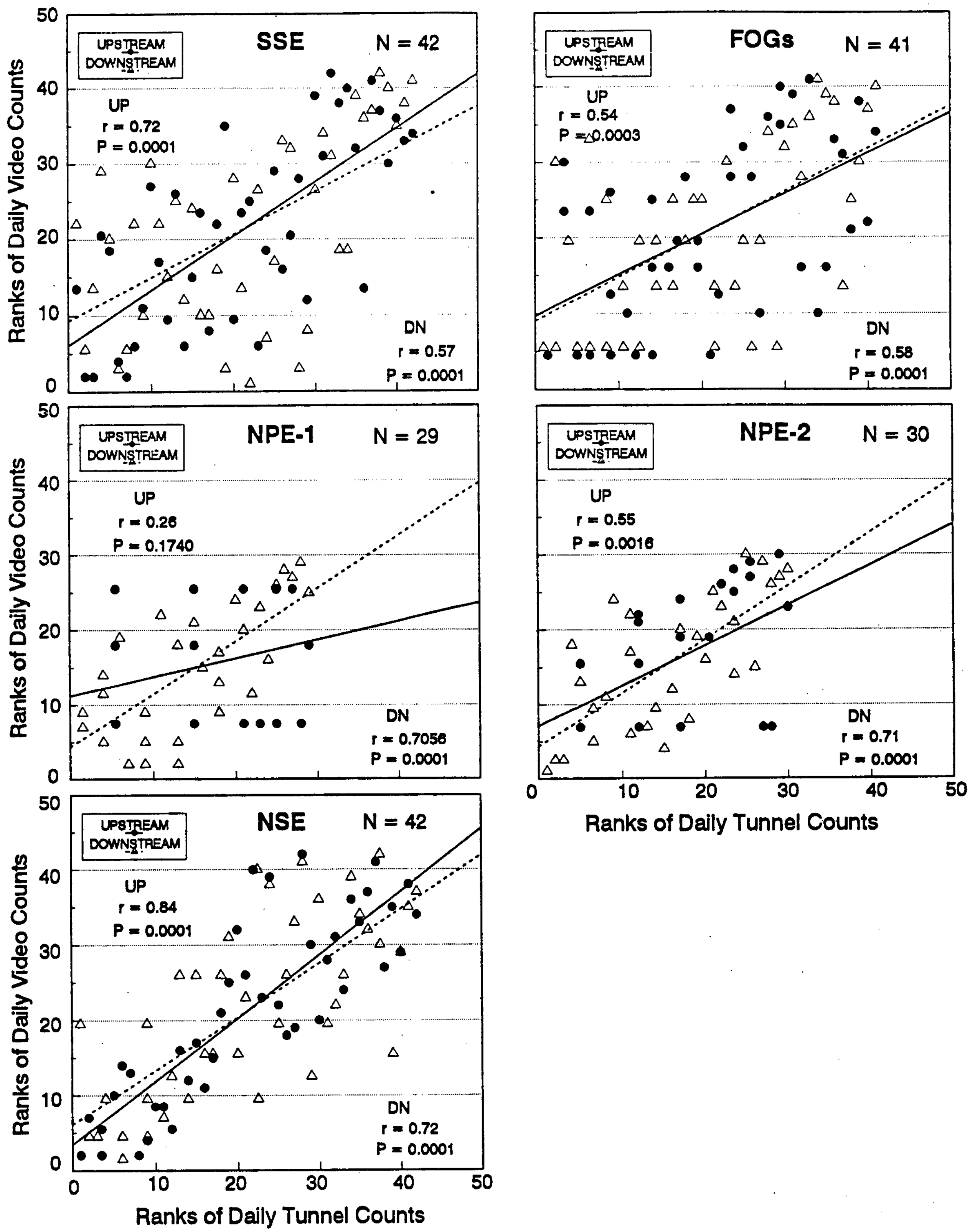


Figure 2. Correlations for ranks of daily upstream and downstream electronic tunnel and video counts at fishway entrances during the summer period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992.

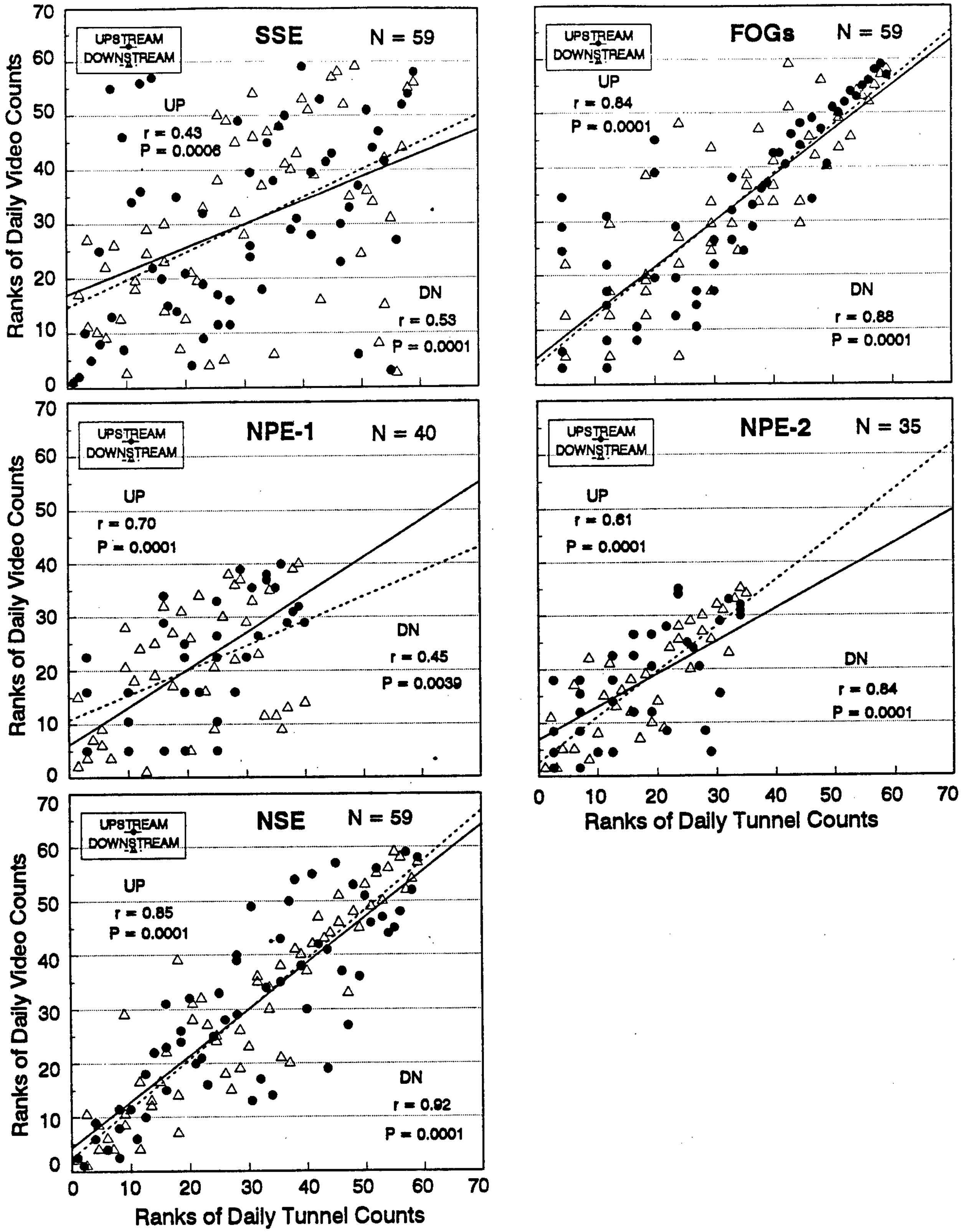


**Figure 3.** Correlations for ranks of daily upstream and downstream electronic tunnel and video counts at fishway entrances during the fall period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992.

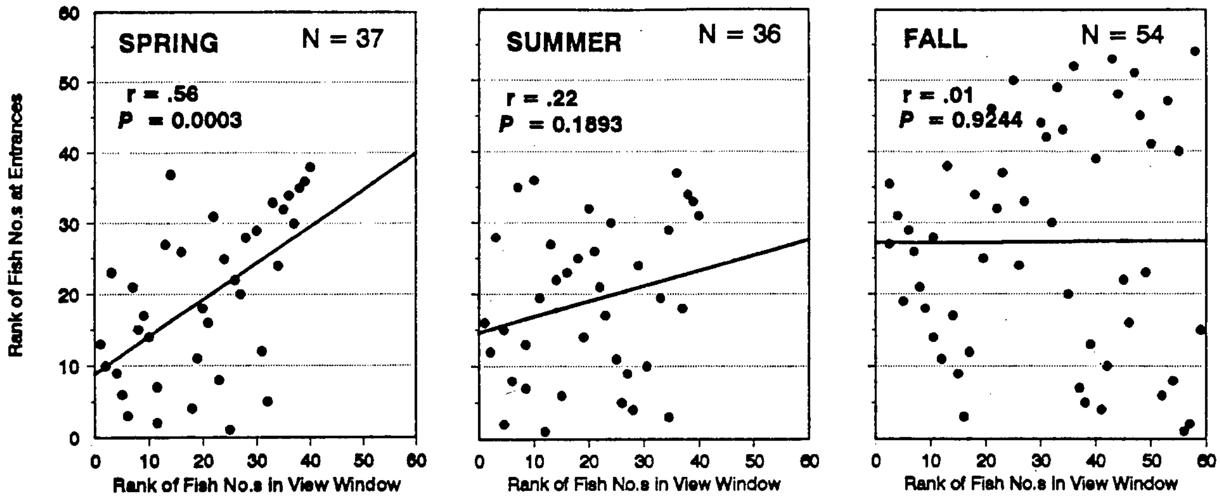


Figure 4. Correlation between daily numbers of fish using fishway entrances, as determined by electronic tunnel counts, and numbers of fish passing the fish viewing window for the spring (29 April - 10 June), summer (11 June - 22 July), and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992. Data represents ranked values.

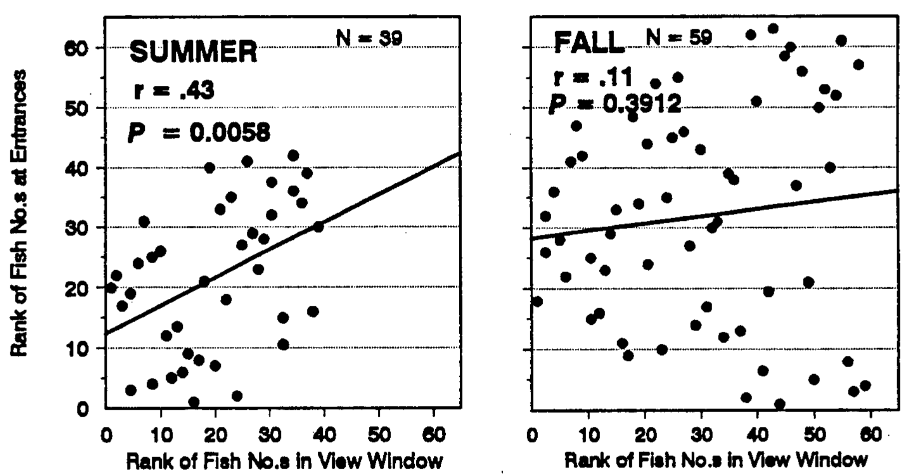


Figure 5. Correlation between daily numbers of fish using fishway entrances, as determined by video observations, and numbers of fish passing the fish viewing window for the summer (11 June - 22 July) and fall (9 September - 10 November) study periods at Lower Granite Dam, Snake River, 1992. Data represents ranked values.

Paired-difference T-tests (non-parametric) between ladder counts and NET tunnel counts or NET video counts indicated that the median difference was significantly different than zero ($P < 0.0005$) for all seasonal periods.

## Tunnel Accuracy

The total number of hours of simultaneous tunnel/video observations varied among entrances (Table 5). In general, we spent more time monitoring SSE and NSE because these entrances contained more video-monitored tunnels.

The species composition of electronic tunnel counts varied by season, entrance, and passage direction. In general, target species comprised a lower proportion of upstream and downstream electronic tunnel counts during the summer (Figure 6) than in the fall (Figure 7). During the summer period, proportions of upstream target counts were highest at the combined FOGs (33%) and lowest at NSE (3%) (Figure 6). Proportions of downstream target counts were highest at NPEs (47%) and lowest at NSE (0%). Non-target species comprised the majority of upstream and downstream tunnel counts at SSE (54%, 79%) and NSE (89%, 73%). During the fall period, a high proportion of upstream target counts were observed at the combined FOGs (93%) and SSE (87%) (Figure 7); low proportions were observed at the NPEs (7%) and NSE (14%). High proportions of downstream counts of target fish were seen at all entrances in the fall, but particularly at the FOGs and NPEs. Upstream counts of non-target fish were relatively high at NSE (43%); downstream counts of non-target species were relatively high at SSE (30%). Proportions of non-target fish counted at other entrances were low or non-existent. Upstream tunnel counts of non-target fish were not evident at the combined FOGs or NPEs during either time period.

Table 5. Total number of hours for simultaneous video/tunnel observations at fishway entrances, Lower Granite Dam, Snake River, 1992.

| | Entrance | | | |
|---|---|---|---|---|
| Season | SSE | FOGs | NPEs | NSE |
| Summer | 8.33 | 3.66 | 6.83 | 8.00 |
| Fall | 9.50 | 5.83 | 9.83 | 11.50 |

Unknown counts were more prevalent at the combined FOGs and NPEs. Counts of small fish usually appeared more frequently in the downstream direction during the summer (Figure 6). False tunnel counts were prevalent at most entrances during the summer and fall, but seemed to be especially common at NPEs in the upstream direction (Figures 6 and 7).

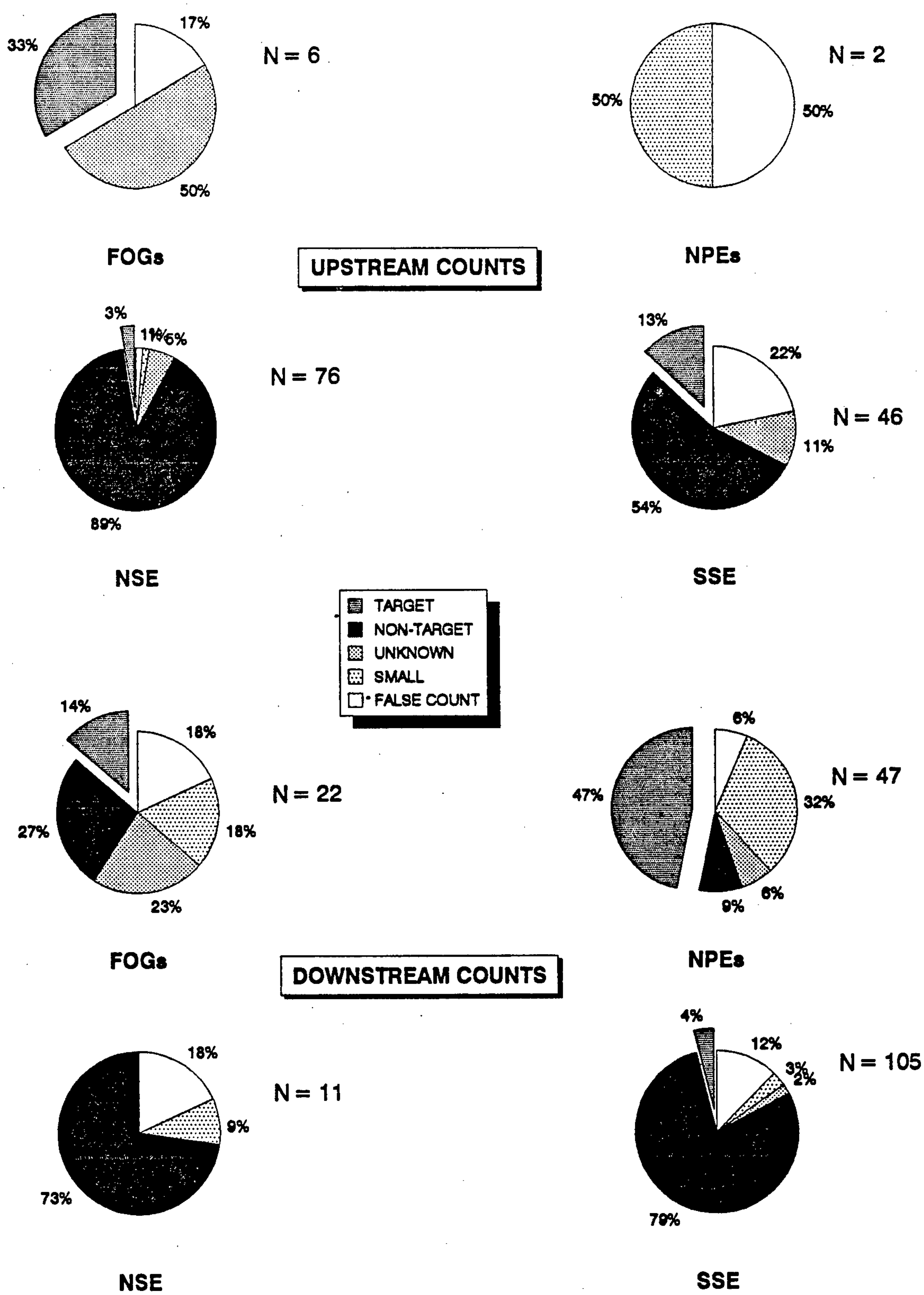


Figure 6. Percent species composition of upstream and downstream electronic tunnel counts at fishway entrances through simultaneous monitoring of video images and electronic fish counters during the summer period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992. (N = number of tunnel counts.)

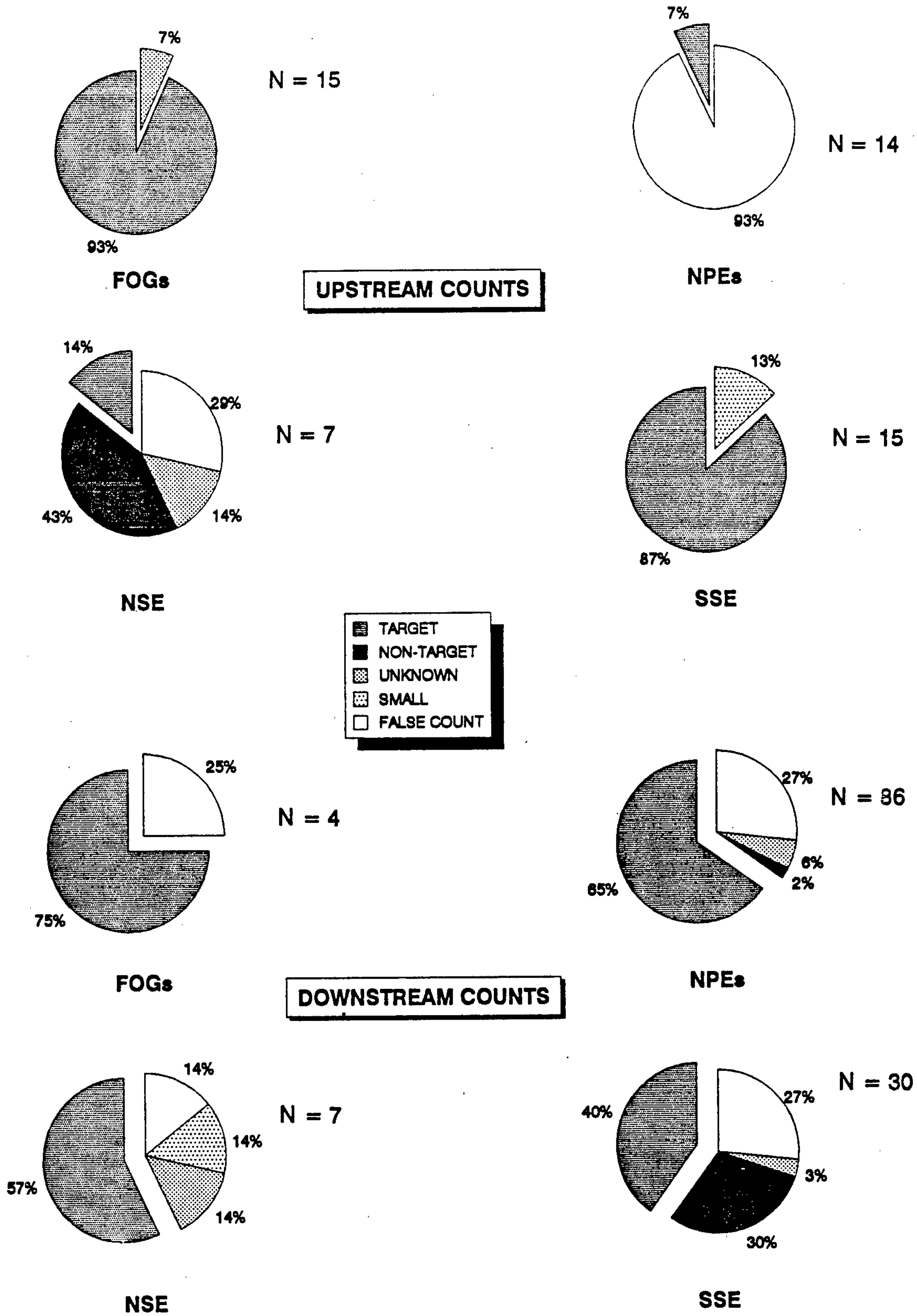


Figure 7. Percent species composition of upstream and downstream electronic tunnel counts at fishway entrances through simultaneous monitoring of video images and electronic fish counters during the fall period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992. (N = number of tunnel counts.)

Composition of fish species passing through tunnels as observed through video observations indicated that count proportions were similar to those recorded by electronic tunnels (Figures 8 and 9). During the summer, the majority of fish seen passing upstream and downstream through SSE (59%, 71%) and NSE (86%, 53%) were non-target species (Figure 8). Upstream and downstream observations of small fish were high at all entrances during the summer.

During the fall period, target fish species moving in the upstream and downstream directions comprised a majority of the observations at all entrances (Figure 9). Upstream and downstream counts of non-target fish contributed most to total fish observed at NSE (27%) and SSE (36%), respectively.

Although sample sizes were small, electronic tunnels located at the FOGs appeared to be the most accurate in detecting directional passage of target fish during both seasonal periods (Figures 10 and 11). In addition, there did not appear to be a directional bias in their counting accuracy (equal accuracy for both upstream and downstream counts). It is difficult to gauge their accuracy in counting non-target fish, since few or none were observed passing through these tunnels.

Small sample sizes also limited effective detection of species-related counting biases among most entrances (Figures 10 and 11). However, at SSE where sample sizes were reasonable, electronic tunnels were more accurate in counting target fish in the upstream direction and non-target fish in the downstream direction during both periods. In contrast, upstream counts of non-target fish at NSE during the fall were approximately 20% more accurate than target fish counts (Figure 11).

NPE tunnels appeared to be the most innaccurate in detecting upstream passage of either target or non-target fish; however, accuracy was improved for counts in the downstream direction, particularly for target species in the fall (Figures 10 and 11).

## Delay and Injury

Impacts on tunnels of fish moving upstream were generally not common in the summer (N = 9) or fall (N = 30) (Tables 6 and 7). However, upstream impacts at the combined FOGs ranged up to 1.1% of the upstream counts during the fall (Table 7). Impacts on tunnels of fish moving downstream were more frequently observed (N = 194, summer; N = 582, fall). During the summer period, downstream impacts were most prevalent at the combined FOGs and NPEs (Table 6). No impacts were observed at SSE and very few at NSE. During the fall, downstream impacts were observed at all entrances, but again particularly at the combined FOGs and NPEs (Table 7).

Downstream and upstream approaches were recorded at all entrances during both seasonal periods, but were most prevalent at the combined FOGs and NSE (Tables 6 and 7).

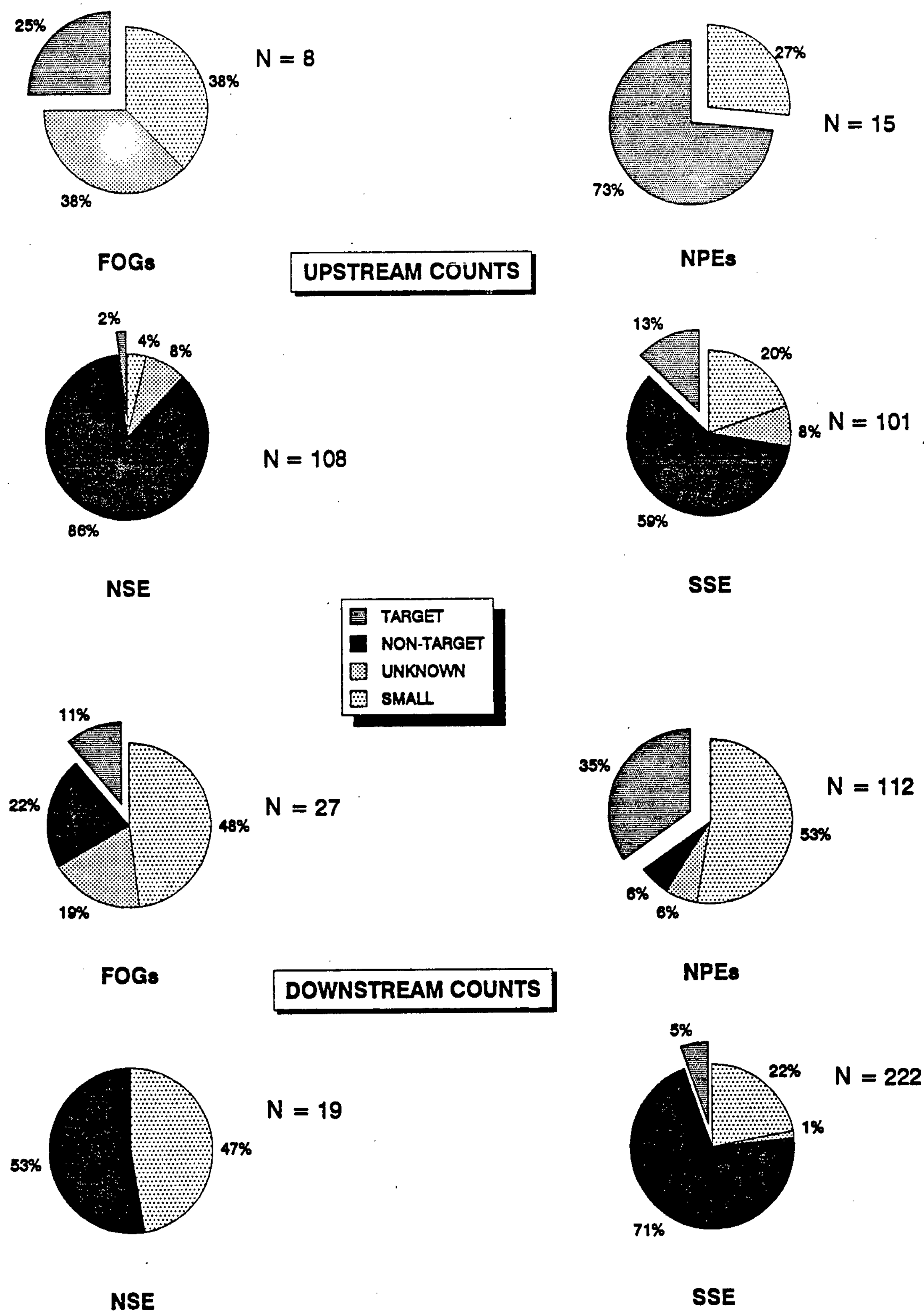


Figure 8. Percent species composition of upstream and downstream video counts at fishway entrances through simultaneous monitoring of video images and electronic fish counters during the summer period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992. (N = number of video counts.)

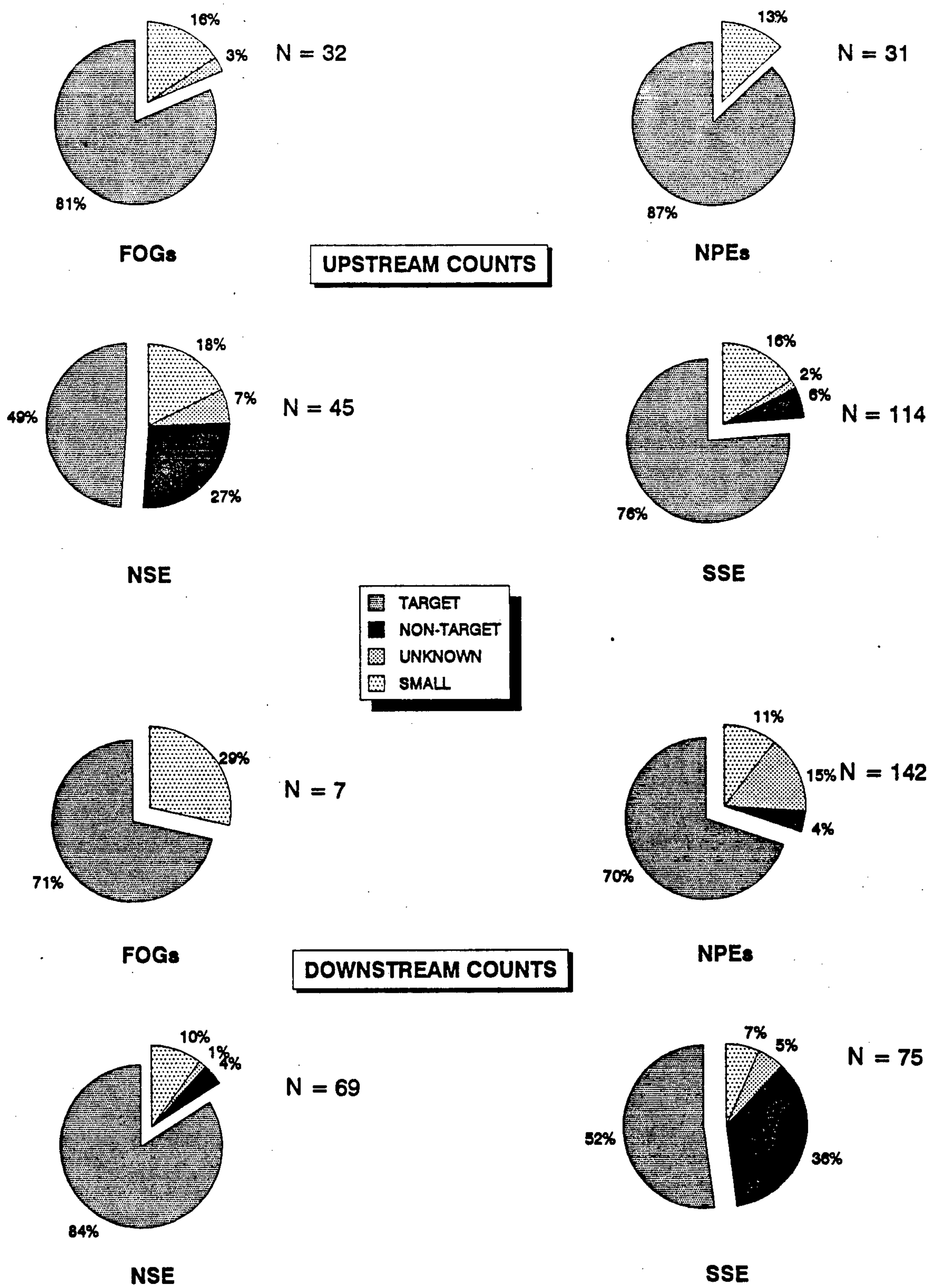


Figure 9. Percent species composition of upstream and downstream video counts at fishway entrances through simultaneous monitoring of video images and electronic fish counters during the fall period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992. (N = number of video counts.)

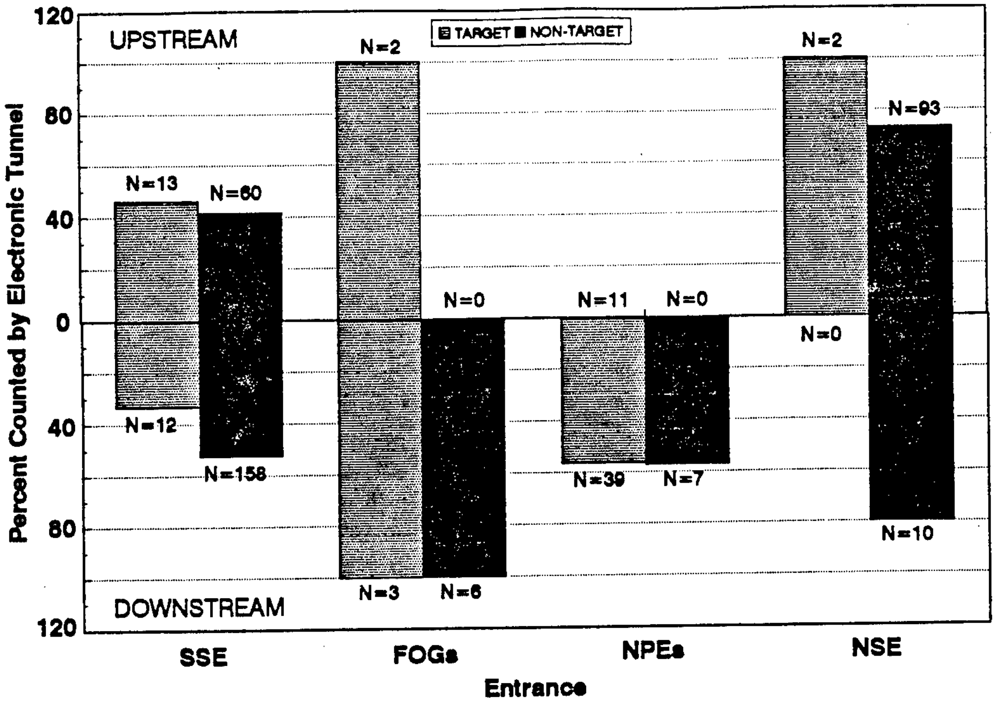


Figure 10. Accuracy of electronic tunnels in counting upstream and downstream passages of target and non-target fish species at fishway entrances during the summer period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992. (N = number of video observed fish passing through electronic tunnel.)

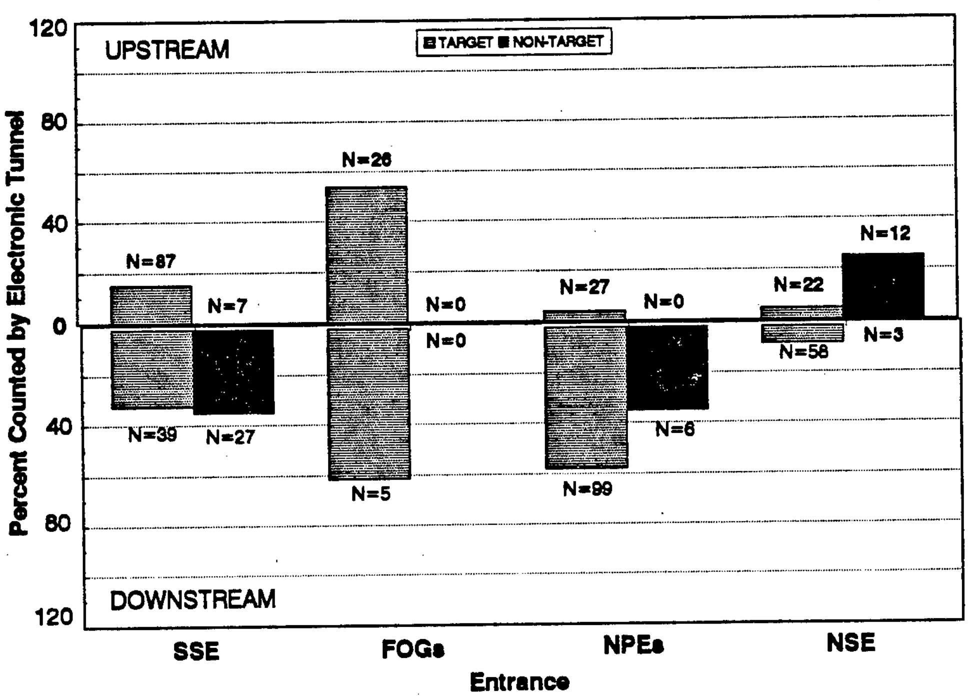


Figure 11. Accuracy of electronic tunnels in counting upstream and downstream passages of target and non-target fish species at fishway entrances during the fall period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992. (N = number of video observed fish passing through electronic tunnel.)

Table 6. Impact and approach indices, as determined through video observations of adult salmonids at fishway entrances during weeks of the summer study period (11 June - 22 July) at Lower Granite Dam, Snake River, 1992.

| Entry, week | Target Up | Target Down | Impacts Up | Impacts Down | Number of approaches | Impact index Up | Impact index Down | Approach index |
|---|---|---|---|---|---|---|---|---|
| SSE, | | | | | | | | |
| 07 | 71 | 47 | 0 | 0 | 9 | 0.000 | 0.000 | 0.076 |
| 08 | 65 | 32 | 0 | 0 | 3 | 0.000 | 0.000 | 0.031 |
| 09 | 376 | 435 | 0 | 0 | 13 | 0.000 | 0.000 | 0.016 |
| 10 | 426 | 200 | 0 | 0 | 25 | 0.000 | 0.000 | 0.040 |
| 11 | 56 | 58 | 0 | 0 | 0 | 0.000 | 0.000 | 0.000 |
| 12 | 83 | 75 | 0 | 0 | 0 | 0.000 | 0.000 | 0.000 |
| FOGs, | | | | | | | | |
| 07 | 16 | 7 | 0 | 1 | 1 | 0.000 | 0.143 | 0.043 |
| 08 | 13 | 3 | 0 | 0 | 3 | 0.000 | 0.000 | 0.188 |
| 09 | 53 | 80 | 1 | 15 | 2 | 0.019 | 0.188 | 0.015 |
| 10 | 149 | 61 | 0 | 4 | 1 | 0.000 | 0.066 | 0.005 |
| 11 | 307 | 21 | 1 | 2 | 4 | 0.003 | 0.095 | 0.012 |
| 12 | 93 | 13 | 0 | 3 | 0 | 0.000 | 0.231 | 0.000 |
| NPE-1, | | | | | | | | |
| 07 | 4 | 8 | 0 | 0 | 1 | 0.000 | 0.000 | 0.083 |
| 08 | 5 | 68 | 0 | 2 | 1 | 0.000 | 0.030 | 0.014 |
| 10 | 9 | 437 | 1 | 13 | 7 | 0.111 | 0.030 | 0.016 |
| 11 | 5 | 116 | 0 | 4 | 0 | 0.000 | 0.034 | 0.000 |
| NPE-2, | | | | | | | | |
| 07 | 8 | 230 | 2 | 5 | 10 | 0.250 | 0.022 | 0.042 |
| 09 | 134 | 2536 | 2 | 125 | 54 | 0.015 | 0.049 | 0.020 |
| 11 | 2 | 302 | 0 | 1 | 0 | 0.000 | 0.003 | 0.000 |
| 12 | 7 | 218 | 0 | 17 | 2 | 0.000 | 0.078 | 0.009 |
| NSE, | | | | | | | | |
| 07 | 324 | 50 | 0 | 1 | 9 | 0.000 | 0.020 | 0.024 |
| 08 | 508 | 345 | 0 | 0 | 14 | 0.000 | 0.000 | 0.016 |
| 09 | 754 | 205 | 1 | 1 | 20 | 0.001 | 0.005 | 0.021 |
| 10 | 470 | 46 | 1 | 0 | 11 | 0.002 | 0.000 | 0.021 |
| 11 | 66 | 32 | 0 | 0 | 1 | 0.000 | 0.000 | 0.010 |
| 12 | 45 | 29 | 0 | 0 | 5 | 0.000 | 0.000 | 0.068 |

Table 7. Impact and approach indices, as determined through video observations of adult salmonids at fishway entrances during weeks of the fall study period (9 September - 10 November) at Lower Granite Dam, Snake River, 1992.

| Entry, week | Target Up | Target Down | Impacts Up | Impacts Down | Number of approaches | Impact index Up | Impact index Down | Approach index |
|---|---|---|---|---|---|---|---|---|
| SSE, | | | | | | | | |
| 01 | 184 | 106 | 0 | 1 | 6 | 0.000 | 0.009 | 0.021 |
| 02 | 3510 | 716 | 0 | 11 | 57 | 0.000 | 0.015 | 0.013 |
| 03 | 2756 | 1111 | 0 | 2 | 32 | 0.000 | 0.002 | 0.008 |
| 04 | 2554 | 1936 | 0 | 19 | 121 | 0.000 | 0.010 | 0.027 |
| 05 | 347 | 302 | 0 | 5 | 6 | 0.000 | 0.017 | 0.009 |
| 06 | 1043 | 875 | 0 | 12 | 44 | 0.000 | 0.014 | 0.023 |
| 07 | 1494 | 567 | 0 | 2 | 42 | 0.000 | 0.004 | 0.020 |
| 08 | 537 | 376 | 0 | 10 | 14 | 0.000 | 0.027 | 0.015 |
| 09 | 1000 | 883 | 0 | 13 | 61 | 0.000 | 0.015 | 0.032 |
| FOGs, | | | | | | | | |
| 01 | 162 | 71 | 1 | 6 | 13 | 0.006 | 0.085 | 0.056 |
| 02 | 491 | 146 | 4 | 45 | 81 | 0.008 | 0.308 | 0.127 |
| 03 | 743 | 139 | 4 | 34 | 74 | 0.005 | 0.245 | 0.084 |
| 04 | 1775 | 275 | 17 | 61 | 114 | 0.010 | 0.222 | 0.056 |
| 05 | 18 | 26 | 0 | 0 | 1 | 0.000 | 0.000 | 0.023 |
| 06 | 178 | 79 | 2 | 13 | 38 | 0.011 | 0.165 | 0.148 |
| 07 | 65 | 17 | 0 | 3 | 11 | 0.000 | 0.176 | 0.134 |
| 08 | 30 | 7 | 0 | 3 | 2 | 0.000 | 0.429 | 0.054 |
| 09 | 10 | 3 | 0 | 1 | 1 | 0.000 | 0.333 | 0.077 |
| NPE-1, | | | | | | | | |
| 01 | 14 | 167 | 0 | 8 | 10 | 0.000 | 0.048 | 0.055 |
| 02 | 44 | 1794 | 0 | 17 | 59 | 0.000 | 0.009 | 0.032 |
| 04 | 23 | 1102 | 0 | 65 | 69 | 0.000 | 0.058 | 0.061 |
| 05 | 5 | 68 | 0 | 2 | 4 | 0.000 | 0.029 | 0.055 |
| 07 | 204 | 480 | 0 | 33 | 18 | 0.000 | 0.069 | 0.026 |
| 08 | 45 | 169 | 0 | 23 | 6 | 0.000 | 0.136 | 0.028 |
| NPE-2, | | | | | | | | |
| 01 | 35 | 282 | 0 | 13 | 3 | 0.000 | 0.046 | 0.009 |
| 03 | 99 | 1714 | 0 | 19 | 27 | 0.000 | 0.011 | 0.015 |
| 06 | 74 | 499 | 0 | 56 | 7 | 0.000 | 0.112 | 0.012 |
| 07 | 100 | 504 | 0 | 32 | 15 | 0.000 | 0.063 | 0.025 |
| 09 | 20 | 153 | 0 | 26 | 11 | 0.000 | 0.170 | 0.063 |
| NSE | | | | | | | | |
| 01 | 308 | 297 | 1 | 3 | 25 | 0.003 | 0.010 | 0.041 |
| 02 | 2456 | 3802 | 0 | 17 | 519 | 0.000 | 0.004 | 0.083 |
| 03 | 2460 | 2080 | 0 | 7 | 271 | 0.000 | 0.003 | 0.060 |
| 04 | 2025 | 1257 | 0 | 9 | 494 | 0.000 | 0.007 | 0.151 |

Table 7. Continued.

| Entry, week | Target Up | Target Down | Impacts Up | Impacts Down | Number of approaches | Impact index Up | Impact index Down | Approach index |
|---|---|---|---|---|---|---|---|---|
| NSE | | | | | | | | |
| 05 | 194 | 26 | 0 | 0 | 11 | 0.000 | 0.000 | 0.050 |
| 06 | 481 | 287 | 0 | 2 | 88 | 0.000 | 0.007 | 0.115 |
| 07 | 357 | 449 | 1 | 7 | 79 | 0.003 | 0.016 | 0.098 |
| 08 | 94 | 101 | 0 | 2 | 54 | 0.000 | 0.020 | 0.277 |
| 09 | 41 | 48 | 0 | 0 | 12 | 0.000 | 0.000 | 0.135 |

## Camera Use and Logistics

### Camera Performance

Although cameras were submerged almost continuously during the summer (42 days) and fall (63 days) study periods, we observed no leakage or other malfunctions attributable to failure of the camera's polyvinylchloride (PVC) housing. During those periods, several cameras were deployed in water velocities in excess of 8 feet per second (fps) and occasionally subjected to impacts by passing fish, yet no damage to the camera was detected.

Although several protective mechanisms were designed into the camera to protect the silicon intensifier target (SIT) tube, several precautions were taken to lengthen its life expectancy. Since a small intense light source was potentially more damaging than viewing a bright light from a one- or two-foot distance, cameras were not pointed at the sun or other intense light sources. Additionally, to prevent image "burns" and to protect low-light sensitivity, we did not fix the camera on bright or high-contrast scenes for an extended period of time.

We identified several precautions and implemented standard procedures to prevent damage to the camera while it was not in operation. To avoid placing cameras on a flat surface while performing repairs or camera rotations, we fabricated "cradles" that supported the camera and prevented them from rolling. Cameras that needed to be delivered to another location or returned for repair were transported in a specially fabricated case that contained a protective foam-rubber lining.

To ensure that proper electrical connections were made from the camera to the camera cable, all connections were cleaned with ethyl alcohol prior to each deployment. A silicone spray was also applied to lubricate connections and increase their life expectancy.

We experienced two mechanical failures that required us to return cameras for service. The mechanical iris-stop on several cameras failed causing the iris to close too far. As a result, the image intensifier sensed the excess closure and sent a signal to open the iris. However, because the intensifier acted more quickly than the lens, the iris opened too far, and the resulting

fluctuations in light-levels caused the image to oscillate. The problem was corrected by using nylon instead of polyvinyl in the construction of the iris-stop. Four cameras were manufactured with the polyvinyl iris-stop. They were returned to Photosea-Hydrovision during July and August for repair. The second mechanical failure was a broken solder joint in the beam-adjustment potentiometer on one camera, which resulted in the formation of a dark circle around the perimeter of the video image. However, the dark circle did not significantly affect our ability to identify fish passage. The problem was repaired at the conclusion of our research.

We identified several factors that influenced image quality, including distance of the camera from the water surface, turbidity, and time of year. If cameras were positioned too close to the water surface, the image would often be too bright for effective imaging. This was evident at SSE during the summer when water levels were the lowest. It was then necessary to deploy a tarp over the tunnel frame to provide shade to the cameras. This problem was exacerbated by non-laminar water surface flow that created erratic light penetration to the cameras, thus increasing the probability of image oscillation. Conversely, cameras deployed too deep in the collection channel often had images that were too dark for effective imaging. This was the case at NSE; cameras were often deployed in water 20 feet deep where there was little or no direct light.

The effect of lighting conditions on video images varied between seasonal periods. During the summer period when the sun was higher on the horizon, we could image successfully until sunset. However, during the fall when the sun set behind the ridge on the south shore, conditions became too dark one-half hour prior to sunset.

In general, visibility (as measured through secchi disk observations) remained above four feet throughout the course of our study. However, as visibility approached the four-foot level, we began to lose the ability to identify fish effectively. This was especially true when coupled with the lower light levels found in deeper water at locations such as the north end of the common collection channel.

### Recording and Tape Review Time

All VCRs performed consistently and effectively over the course of our study. Although the manufacturer specified that the time-lapse VCRs were to operate in a 41 - 104° Fahrenheit temperature range, we often had to expose them to temperatures ranging between 30° F and 115° F. Although equipment was sheltered from the rain and dust, we could not regulate humidity or control condensation.

In total, we recorded approximately 12,500 hours of video tape during both seasonal study periods. We determined that, on the average, one person could review 5.17 hours of tape during a one-hour tape review session. Factors that influenced tape review time included the number of fish present, quality of the video image, and water clarity. At tunnels located in the collection channel (SSE and NSE), large groups of carp would often remain within the camera's field of view throughout a day. This tended to confound the image and make identification of passing fish more difficult. Poor image

quality contributed to increased review times as images had to be replayed several times to properly identify species of fish and determine their direction of passage.

We determined that at our rate of review, two staff members reviewing tape for 40 hours each week could theoretically review 12,500 tape-hours in a 30-week period. However, during the study, we had 1 to 2 staff members reviewing tape 7 days per week; this allowed us to review all the tape in a 22-week period.

The number of hours that could be recorded on an individual tape varied with the recording mode used. Originally, we had attempted to record on 72-hour mode. This would have permitted 5 days of recording on a single VHS tape and would have allowed us to use only 350 tapes over the course of our study. However, after reviewing 72-hour tapes, we surmised that we were obtaining only 1 or 2 frames per passage of an individual fish. This greatly diminished our ability to determine fish species or the direction of passage. As a result, we determined that the rate at which fish fell out (and to a lesser degree, entered) was a function of the velocity of the water at that entrance or tunnel location. Therefore, to increase the number of frames for an individual passage event, we decreased the time-lapse rate. We subsequently recorded on a 48-hour mode at SSE and NSE (water velocities were 2-3 fps) and on a 24-hour mode at the NPEs and FOGs (water velocities were 7-10 fps).

## Camera Frames

### NSE Camera Frame

A preliminary design for a camera frame to be mounted directly at NSE-1 was developed and the frame was fabricated by University of Idaho metal shop personnel during mid-May. The camera frame was constructed of 1.5-inch diameter metal pipe, and metal "sleeves" attached the frame to the weir gate hoist cables (Figure 12). The camera mounts were located one above the other (2-foot separation) midway across horizontal bars and allowed for adjustment of the camera angle in either the upstream or downstream orientations. The height of the camera mounts above the weir gate could be adjusted to accommodate seasonal variations in weir gate depths. The frame weighed approximately 40 pounds and was easily handled by two people. The narrow profile of the frame allowed for easy deployment between the gate slot and weir-gate hoists. All of the frame edges and welds were ground to create smooth and un-abrasive surfaces.

Initial deployment of the frame was accomplished by raising the weir gate (via the hoist) until the top of the weir gate was 2-3 feet from the fishway deck. The frame was fitted on top of the gate and the sleeves were clamped to the hoist cable. After deployment of the weir gate and camera frame (without video cameras), we detected no excessive vibration or structural failures.

We conducted three tests to determine successfulness of camera imaging for species identification: (1) two cameras were deployed directed upstream into the fishway, (2) two cameras were deployed directed downstream into the tailrace, and (3) one camera was deployed facing directly down toward the top of the weir gate.

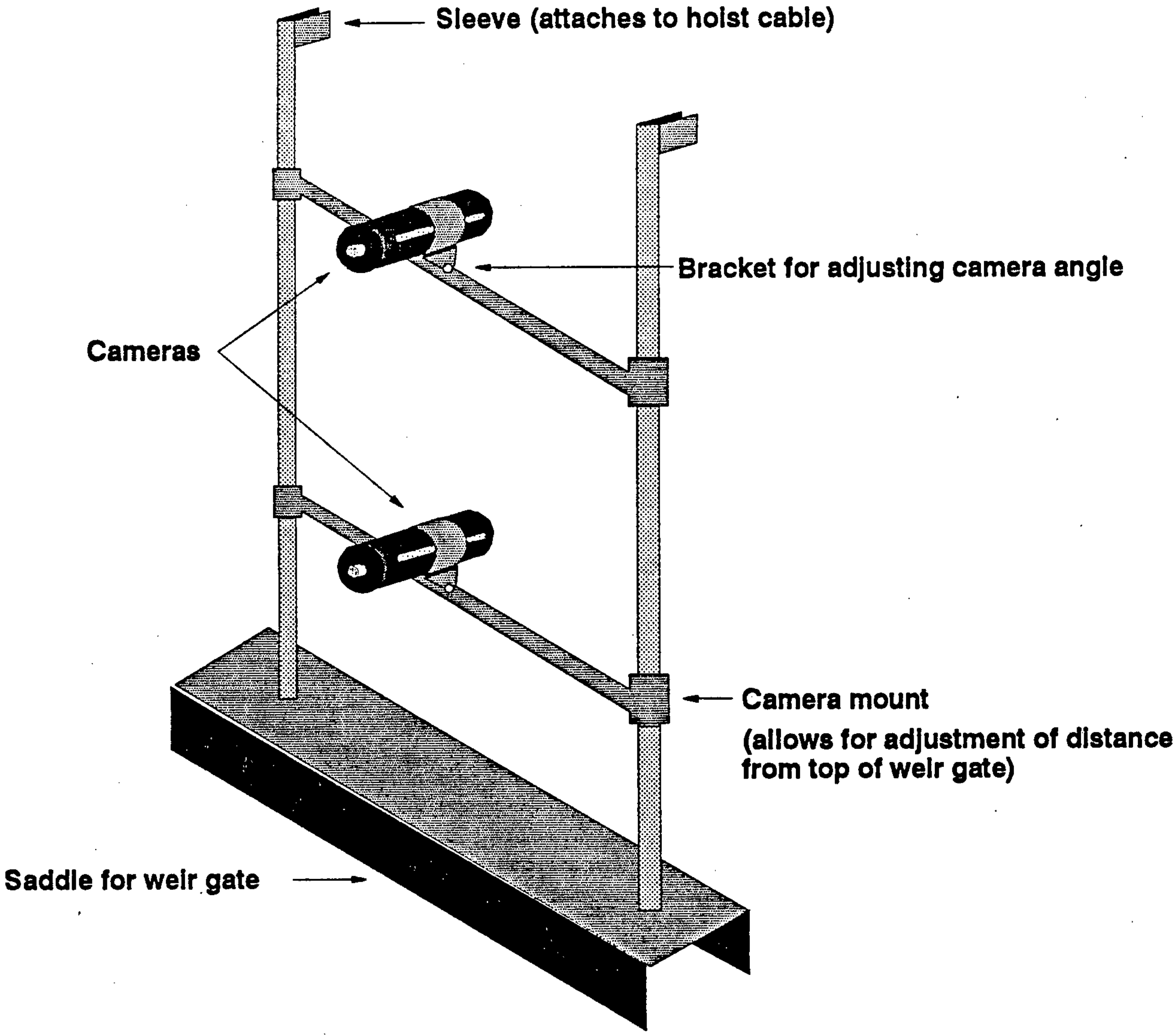


Figure 12. Schematic of camera frame tested at the north and south shore fishway entrances at Lower Granite Dam, Snake River, 1992.

Cameras deployed in the upstream or downstream direction did not provide quality images to adequately identify fish. Review of video taped images indicated that images were dark and shadow-like in appearance. Slight oscillations of the image also contributed to poor picture quality. In addition, recording in 48-hour mode was not suitable as fish moved through the field of view too rapidly. Subsequent adjustments to the imaging angle did not appreciably improve images. We identified a future need to diminish surface lighting, improve backlighting conditions, and incorporate known points of reference.

In general, the test with one camera (top mount) facing down onto the weir gate provided better picture quality. However, the angle of imaging was not suitable because it did not provide us with a lateral view of fish as they passed through the entrance (a lateral view provides information on fin structure that can assist in identification).

The frame, as designed, adequately supported two cameras; we encountered no structural failures during our tests. We detected no excessive vibration of the cameras, or camera frame with cameras mounted, and flow through NSE did not appear to be disrupted by the frame.

**SSE Camera Frames**

Two camera frames were designed, fabricated, and tested for this entrance. The initial frame was constructed by University of Idaho metal shop personnel and was similar in design to the NSE frame, except that it was fitted with a straddle that mounted over the weir gate for frame bottom support (Figure 12). A ladder was fabricated to facilitate access to the downstream side of the entrance and frame deployment.

After initial modifications, we mounted the camera frame onto the SSE-1 weir gate, secured the frame to the hoist cable, and lowered the gate and frame without cameras. When the weir gate was approximately four feet below tailwater, the force of the outflow lifted the frame off the gate resulting in a tremendous amount of strain on the hoist cable. Subsequent means of frame attachment enabled complete (eight feet) submergence of the weir gate; however, water velocities were extremely high and the hoist cables bowed from the exerted pressure. Apparently, the frame did not have the structural integrity needed to withstand the outflow at this entrance.

We redesigned a second camera frame, incorporating increased structural integrity and structures for enhancement of camera imaging (Figure 13). The new frame, developed in cooperation with University of Idaho metal shop personnel, was fabricated by a local metal shop. The frame was designed to rest on top of the existing weir with the bulk of the frame support structure fitting inside the weir gate slots. The design ensured that the entrance dimensions and outflow were not significantly altered. The frame was approximately 12 feet high and 5 feet wide. Two stacked plywood tunnels were located at the bottom of the portion of the frame to decrease the direct effects of surface lighting and provide ideal back-lighting conditions for camera imaging. Tunnel interiors were painted white to provide uniform ambient lighting conditions. Tunnel dimensions were 3.5 feet high x 4 feet wide x 3 feet deep. Camera mounts were located on the upper, lower, and side

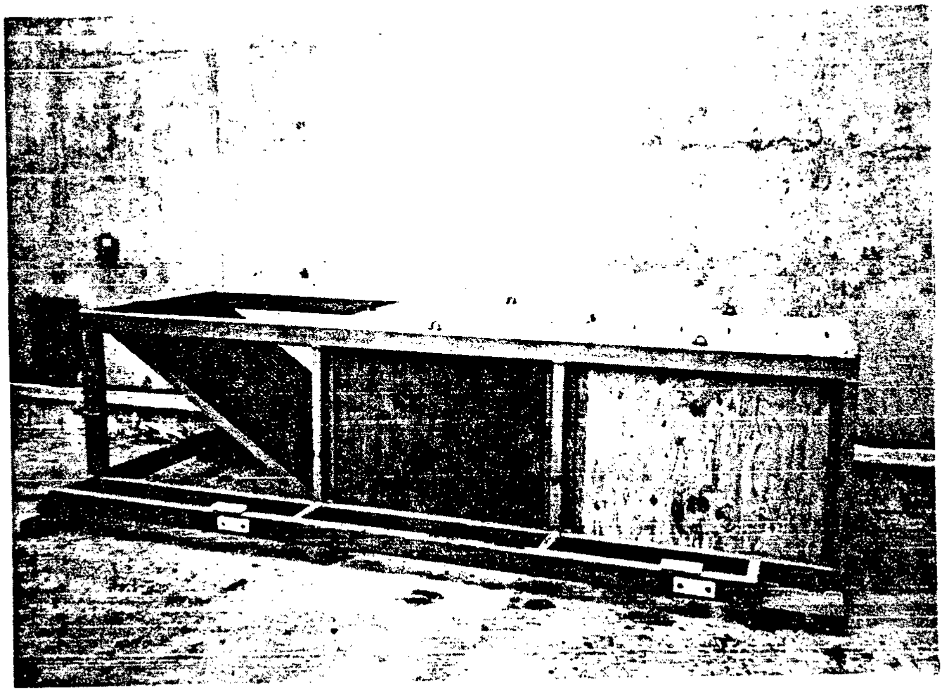

Figure 13. Second camera frame constructed for use in deploying video cameras at the south shore fishway entrance at Lower Granite Dam, Snake River, 1992.

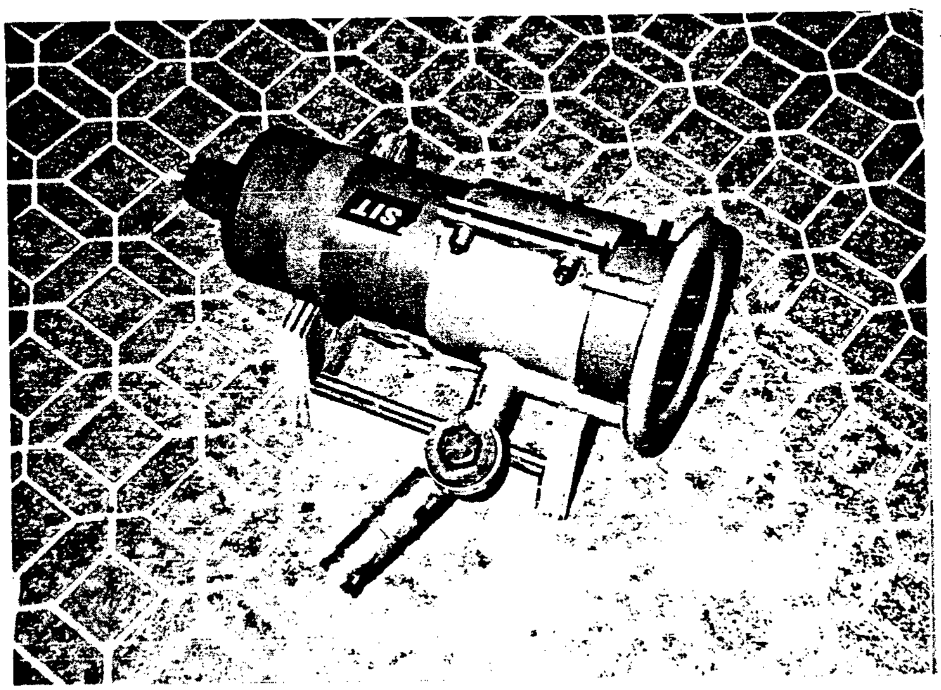

Figure 14. Camera bracket and lens guard used for deploying cameras on the second south shore entrance frame at Lower Granite Dam, Snake River, 1992.

portions of the tunnels. A camera bracket, fabricated with a guard to protect the camera lens, encased the mounted camera (Figure 14). The top portion of the frame consisted of a sloped picketed fence that forced fish to pass through one of the tunnels, but prevented them from becoming impinged when approaching from the upstream direction (Figure 13).

Crane service was required to install and deploy the frame on the weir structure. During initial deployment tests, without the cameras, we observed no detectable vibration or structural failures. Subsequent tests were performed with a camera mounted on the top tunnel and bottom tunnel mount facing upstream (into the fishway) and on the bottom tunnel. Fish passage was taped on 24-hour mode. Despite slightly turbid water, image quality was good and we were able to identify target species passing through the tunnel. In general, the images were bright and showed the shape of passing fish from a lateral view. We observed one target fish impact on the camera, but camera performance was not affected.

## DISCUSSION

Researchers using electronic impedance tunnels to study passage at dams have had to assume that (1) electronic tunnel counts represented passage of adult salmonids, and (2) tunnel performance did not vary among tunnel locations. However, our use of underwater video cameras detected counting biases related to species of fish, entrance location, count direction, and seasonal time period. The major limitation with electronic tunnels was the inability of this technology to discern salmonid-specific passage. Other species in the fishway and tailrace inflated entrance counts, particularly at the shore-based entrances during the summer period. Carp were especially troublesome; girth and size were sufficient to register a count. Even when few non-salmonids were present in the fall, tunnel counts did not accurately represent salmonid passage.

Tunnel performance varied with location. Variability might have resulted from differences in (1) performance between center-electrode and peripheral-electrode tunnels, (2) water velocities, (3) amount of entrapped air or debris passing through the tunnels, and (4) fish behavior. Dunkley and Shearer (1982) noted that counter performance, or accuracy in which fish passages were recorded, differed considerably in their two-year study, even though the same counter was used on each occasion and no alternations to the preset sensitivity level were made.

False counts were greatest at high velocity entrances, such as the FOGs and NPEs where water turbulence and air bubbles are common. False counts were also common at tunnels in the collection channel. Shallow water over the tunnel electrodes results in flow variations at the water surface that can be detected, causing false counts (Simpson 1978). Fish or other objects outside the tunnel can unbalance the detector and cause a count to register (Payne 1978). We frequently observed carp positioning themselves immediately outside of the tunnels, particulary in the collection channel. Poor image quality or water conditions can also make viewing fish passage difficult, thereby giving the appearance that counts are registered in the absence of fish (Dunkley and Shearer 1982). A few fish might have passed undetected along the bottom of the tunnel and elicited a count.

Small fish should not have been counted, but were. Counter sensitivity was calibrated to ignore fish smaller than 20 inches. However, at this level of sensitivity, we were counting only a small portion of the target population. Dunkley and Shearer (1982) reported that an increase in discharge and concomitant decrease in water conductivity increased the sensitivity of the counter so that small fish were counted. Discharge from the powerhouse was greater in the summer than in the fall (**Report A, APPENDIX D**) and a larger percentage of small fish were counted in the summer. The greater count of small fish in the downstream direction may have been due to the tendency for these fish to fall back along the tunnel sides when descending, thereby coming in close contact to the tunnel electrodes.

Electronic tunnels underestimated fallout at the NPEs. Unregistered counts may have resulted from simultaneous passage of more than one fish through the tunnel, with only one fish being detected, fish descending in a sideways orientation, and accelerated fallout. These phenomena were frequently observed on video tape. Dunkley and Shearer (1982) reported that an electronic counter cannot discriminate between one or more fish crossing the counting zone at the same time or following immediately behind one another. The 3-second lag period built into the logic circuitry of our counters could have permitted the hindmost of several fish falling out to escape detection. The sideways orientation during fallout causes the conductivity of the fish's width, rather than its length, to be detected, which is insufficient to trigger a count (Dunkley and Shearer 1982).

The accuracy of electronic tunnel counts also suffered due to limitations in tunnel placement. Tunnel counts from locations representing the south shore and north shore entrances were influenced by the presence of non-target fish and changes in their activity within the fishway. Even if the size of the resident fish population did not change, increased back and forth movement in the fishway probably inflated SSE and NSE counts. This is a good example of why electronic tunnels should not be placed in the common collection channel.

Optimal entrance passage data can only be obtained directly at the entrance. To successfully image and record passage of fish at high velocity fishway entrances, a structurally sound support structure should be used. More importantly, this structure should enhance the imaging environment by decreasing direct surface light, providing known points of reference, and improving backlighting conditions. The second frame designed for SSE-1 was suitable for satisfactory imaging. Water turbidities and lighting conditions were as poor as we had experienced while using video, yet the images we recorded were clear. The tunnel structures themselves were critical for effective camera imaging. However, recording on a 12-hour mode versus a 24-hour mode would provide longer imaging time, as fish passage is rapid in high velocity outflows. In future tests of this design, we suggest the camera orientation be changed to the other side of the frame (looking downstream through the tunnel) to further improve backlighting conditions. Marking known distances on the tunnel wall would aid in approximating fish lengths.

NET counts were not a good indicator of "true" passage to correlate with ladder counts. Subtracting downstream counts from upstream counts often resulted in overall negative passage. Although the correlation of video NET counts with ladder counts was stronger than that of tunnel counts, the

association was still poor and greatly deteriorated during the fall period. Fish behavior within the ladder and at the entrances and lag time between fish entering the fishway and being counted at the fish viewing window may have contributed to the poor correlations. The high degree of fallout, particularly in the fall, undoubtedly greatly decreased the fitness of this indicator.

The fairly strong association between tunnel and video upstream and downstream counts overall suggests the general ability of tunnels to detect differences in passage rates. In general, it appeared that use of entrances by salmonids was similar to that of non-salmonids. The lower correlation between tunnel and video downstream counts may have been a function of differing fish movements and behavior, and the species and size of fish triggering the counts. However, although electronic tunnels do provide a gross measure of directional passage at entrances, errors in recording specific entrance and general fishway passage did occur.

Such errors in counting should preclude the use of tunnel technology to provide accurate and precise estimates of passage for use in evaluating effects of dam operations. Payne et al. (1978) noted that correlations between salmonid entrance into the fishways of Columbia and Snake River dams and the operating conditions of these dams would require very accurate data regarding these events. This is particularly important in light of the complex interrelationships among spill, powerhouse, and fishway operations, discharge and hydraulic effects, and fish behavior.

Our data suggested that the center electrode tunnels at the floating orifice gates were more accurate than the peripheral electrode tunnels at other entrances in detecting directional passage of adult salmon. The desire by fisheries personnel at Bonneville Dam to convert from a center-electrode configuration to a peripheral-electrode system was spurred by the need to reduce tunnel maintenance, change to a more readily available electrode material, and circumvent problems with fish passage between the electrode and the tunnel walls (Payne et al. 1978).

However, the center electrode allows little space for an approaching fish to pass safely between the electrode and the tunnel frame. From our video taped recordings, we observed that the greatest amount of downstream fish impacts and injury occurred at the FOGs with the center-electrode configuration. Fish falling out of these entrances would "strike" the electrode, and either reverse direction or continue to fall out. At times the impacts were severe for salmonids and non-salmonids alike. Downstream impacts were also observed at the NPEs, as fish were carried out by the high velocity outflow. In general, fish fallout and impacts occurred along the top of the tunnel. On occasion, impacts on the camera at the NPEs did occur.

In general, video cameras and their associated equipment performed effectively over the range of existing environmental conditions. The environmental condition most critical to video usage was visibility, as affected by turbidity and light conditions; visibility less than four feet created difficulty in fish identification. With good visibility, underwater video proved to be a viable method for accurately obtaining fish passage information. Our studies suggest the optimum configuration for underwater video camera use is usually a side-mounted location with camera directed

downstream, placed six or more feet deep. Underwater video cameras have been used to count fish in other applications (Dunkley and Shearer 1982, Hatch et al. 1993, Irvine et al. 1991, Johnson et al. 1982). However, this recent technological development merits continued research in its use as a valid monitoring system.

It is essential that operating environments are thoroughly described prior to use of low-light video equipment. Whenever possible, test deployments should be conducted to identify problem locations and document lighting conditions. Additionally, expected ranges of turbidity should be determined and controlled tests should be performed to assess effective imaging ranges at various levels of turbidity. Budgets should reflect expenditures necessary for repairs and replacements of camera equipment beyond the warranty period.

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## RECOMMENDATIONS

1) Electronic tunnels can not be used to obtain accurate and precise passage information when it is to be correlated with dam operations.

2) If electronic impedance tunnels are ever to be used in future research, we recommend (1) that tunnels are not placed in the common collection channel, but directly at all entrances, (2) that center electrode tunnels not be used to monitor passage due to injury effects, and (3) that tunnels be used only to gather gross estimates of passage.

3) Continue to evaluate the efficacy of underwater video cameras as a viable technology for obtaining passage information, particularly over a multi-year study.

4) If underwater video studies are to be implemented, preparations should include (1) test deployments to identify problem locations and document lighting and velocity conditions, (2) assessment of turbidity and effective imaging ranges and angles, and (3) design of structurally sound camera frames that incorporate partitions for decreasing direct surface light, providing known points of reference, and improving backlighting conditions.

5) Further tests with the SSE camera frame should include rearranging the camera to a downstream orientation and affixing distance markers on the partitions.

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